UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Market Quality Research Division

REPORTS FROM COTTON DIVISION STANDARDIZATION SECTION

COLOR LABORATORY, 1948 - 1964

On Grade, Color, Trash, Luster of Cotton, and

On Illumination for Cotton Classing and Color Rendering

Compiled by

Dorothy Nickerson
Research Color Technologist

Assembled for
reference

Washington, D.C.
October 1964

76605

REPORTS FROM COTTON DIVISION STANDARDIZATION SECTION COLOR LABORATORY, 1948 - 1964

Compiled by
Dorothy Nickerson,* Research Color Technologist

Grade, Color, Trash, Luster Studies, 1950-1964

		Report number
1950	Nickerson, D. FOREIGN-MATTER CONTENT IN BALES OF COTTON USED FOR GRADE STANDARDS. Text. Res. Jour., 20:277-278.	1
	Nickerson, D. COLOR MEASUREMENTS OF COTTON. Preliminary (first) Report on Cotton Colorimeter. 18 pp.	2
	Nickerson, D., Hunter, R. S., and Powell, Marshall G. NEW AUTOMATIC COLORIMETER FOR COTTON. Jour. Opt. Soc. Am., 40:446-449.	3
1951	Nickerson, D. NEW AUTOMATIC COTTON COLORIMETER FOR USE IN COTTON QUALITY SPECIFICATION. Text. Res. Jour., 21:33-38.	4
1953	Nickerson, D. COLOR MEASUREMENTS OF COTTON. Second Report on Nickerson-Hunter Cotton Colorimeter. 38 pp.	5
1954	Nickerson, D. COLOR OF COTTON GRADE STANDARDS, 1909-54. 15 pp.	6
1956	Nickerson, D. COLOR MEASUREMENT DATA RELATING TO GRADE STANDARDS FOR COTTON AND COTTON LINTERS. 50 pp. (May)	7
	GRADE STANDARDS: COLOR AND TRASH MEASUREMENTS. Summary of above 50-page report. 10 pp. (Oct.)	8
1957	Nickerson, D. A NEW COTTON LUSTERMETER FOR YARNS AND FIBERS. Text. Res. Jour., 27:111-123.	9
1958	Nickerson, D. and Newton, F. E. GRADE AND COLOR INDEXES DEVELOPED FOR EVALUATING RESULTS OF USDA COTTON FINISHING TESTS. AMS-245. 14 pp.	10

---

* Market Quality Research Division, Agricultural Research Service, formerly Head, Standardization Section, Standards and Testing Branch, Cotton Division, Agricultural Marketing Service.

Continued

1959 Nickerson, D. and Tomaszewski, J. J.
COLOR MEASUREMENTS OF GRADE STANDARDS, 1952-1959. 11 ✓
No. 1 Report prepared for 1959 Universal
Grade Standards Conference, May. 7 pp.

Nickerson, D. and Tomaszewski, J. J.
SUMMARY OF COLOR MEASUREMENTS FROM SURVEYS OF 12 ✓
COTTONS CLASSED IN 8 CROP YEARS, 1951 TO 1958.
No. 2 Report prepared for 1959 Universal
Grade Standards Conference, May. 13 pp.

Nickerson, D., Tomaszewski, J. J., and Newton, F. E.
TRASH AND COLOR. 13
No. 3 Report prepared for 1959 Universal
Grade Standards Conference, May. 16 pp.

Nickerson, D. and Tomaszewski, J. J.
COLOR CHANGE IN STORAGE. 14 ✓
No. 4 Report prepared for 1959 Universal
Grade Standards Conference, May. 15 pp.

Newton, F. E.
ROUGHNESS AS A FACTOR OF COTTON GRADE MEASURED 15
BY SPINNING TESTS. 6 pp.

1960 Nickerson, D.
COTTON COLORIMETER. An Aid in Extending Knowledge 16 ✓
of Cotton Quality. A report given at the Open
House of the ACMI, Clemson, S. C. (May) 15 pp.

Smith, H. R.
A NEW COTTON TRASHMETER. A report before the 1960 17 ✓
Cotton Research Clinic, Asheville, N. C. (May)
10 pp.

Newton, F. E.
A NEW LOOK AT COTTON QUALITY RELATIONSHIPS. Based 18
on Statistical Studies of Cottons, 1946-59, that
include both classification and laboratory tests.
A report given at the 1960 Cotton Research Clinic,
Asheville, N. C. (June) 23 pp.

Nickerson, D.
COLOR CODE FOR RELATING COLOR MEASUREMENTS OF RAW 19 ✓
COTTON TO COLOR IN GRADE STANDARDS. AMS-411. 3 pp.

1961 Smith, H. R.
WHERE WE ARE IN MEASURING COLOR AND TRASH. 20 ✓
A report before the 1961 Cotton Research Clinic,
Memphis, Tennessee. (May) 8 pp.

Continued

1962 Nickerson, D.
RECENT TRENDS IN TRASH CONTENT OF RAW COTTON CREATE A PROBLEM IN GRADE STANDARDS. AMS-454. 15 pp. 21

Nickerson, D., Newton, F. E., and Fry, E. G.
COTTON QUALITY RELATIONSHIPS BETWEEN SELECTED MEASURES OF QUALITY AND FIBER, YARN, AND PROCESSING PROPERTIES. AIB 257, and Supplement to AIB 257. 22

Tomaszewski, J. J.
1961 GRADE SURVEYS OF AMERICAN UPLAND AND AMERICAN EGYPTIAN COTTONS. 25 pp. 34

1963 Smith, H. R.
THE USE OF COLOR AS A MEASUREMENT OF COTTON QUALITY. 17 pp. 23

Tomaszewski, J. J.
GRADE SURVEYS OF 1962 CROP AMERICAN UPLAND AND AMERICAN EGYPTIAN COTTONS. 15 pp. 35

1964 Nickerson, D., and Tomaszewski, J. J.
EFFECTS OF STORAGE ON COTTON QUALITY: Fiber, Spinning, and Finishing Tests on 38 Cottons Before and After Storage Under Controlled Conditions. 43 pp. (Jan.) 36

Nickerson, D.
STANDARDIZATION OF TEST SAMPLES USED TO SET ORIGINAL SCALES, AND TO CALIBRATE NICKERSON-HUNTER COTTON COLORIMETER. 21 pp. (Jan.) 37

Nickerson, D., and Griffith, S. R.
Notes on A HISTORY OF UNITED STATES COTTON STANDARDS AND RELATED SUBJECTS — With An Annotated Bibliography. 61 pp. (100 copies, May) 38

A.S.T.M.
METHOD OF TEST FOR COLOR OF RAW COTTON USING THE NICKERSON-HUNTER COTTON COLORIMETER. (D2253-64T.) (June) 39

Nickerson, D.
PATTERN OF COLOR CHANGE EMERGES FROM 3-YEAR STORAGE STUDY OF COTTON GRADES. Letter to the Editor, Textile Research Journal, 34:645-647 (July). 40

Continued

Illumination - 1948 to 1964

1948 Nickerson, D.
THE ILLUMINANT IN TEXTILE COLOR MATCHING. An Illuminant to Satisfy Preferred Conditions of Daylight-Match. Illum. Engin., 43:416-467. General Report of Subcommittee on I.S.C.C. Problem 13. (Full report.) 24

Nickerson, D.
THE ILLUMINANT IN TEXTILE COLOR MATCHING. Jour. Opt. Soc. Am., 38:458-466. Summary of Report of Subcommittee on I.S.C.C. Problem 13. 25

1952 Nickerson, D.
COTTON CLASSING BY ARTIFICIAL LIGHT. Illum. Engin., 47:135-142. 26 ✓

1956 Nickerson, D.
ACHIEVEMENT OF LIGHTING STANDARDS FOR THE GRADING OF COTTON. AMS-94. 29 pp. 27 ✓

1958 Nickerson, D.
MEASUREMENT AND SPECIFICATION OF COLOR RENDITION PROPERTIES OF LIGHT SOURCES. Illum. Engin., 53:77-90. 28 ✓

1959 A.S.T.M.
RECOMMENDED PRACTICE FOR LIGHTING COTTON CLASSING ROOMS FOR COLOR GRADING. (D1684-61) 11 pp. 29 ✓

1960 Nickerson, D.
LIGHT SOURCES AND COLOR RENDERING. Jour. Opt. Soc. Am., 50:57-69. Invited paper to summarize the present status of work in this field. 30

1962 Illuminating Engineering Society.
INTERIM METHOD OF MEASURING AND SPECIFYING COLOR RENDERING OF LIGHT SOURCES. Report of Subcommittee on Color Rendering. Illum. Engin., 57:471-495, available as I.E. reprint, 27 pp. 31 ✓

1963 Nickerson, D. (Com. Chairman)
OCTOBER 1963 REPORT OF SUBCOMMITTEE ON COLOR RENDERING, I.E.S. LIGHT SOURCES COMMITTEE. 3 pp. 32

CIE METHOD OF MEASURING AND SPECIFYING COLOUR RENDERING OF LIGHT SOURCES, based on Vienna draft. 14 pp. (Report attached to above #32.) 33

Nickerson, D.
COLOR CHANGE WITH CHANGE OF LIGHT SOURCE—An Unsolved Problem in Colorimetry. Acta Chromatica (Japan), 1:45-50 (Oct.). 41

Continued

1964 Nickerson, D.
CIE COMMITTEE AGREES ON METHOD OF RATING LAMPS FOR COLOR RENDERING. Illum. Engin., 59:57. (Jan.) 42

Nickerson, D. and Jerome, C. W.
COLOR RENDERING OF LIGHT SOURCES: CIE METHOD OF SPECIFICATION AND ITS APPLICATION. Preprint of paper for 1964 I.E.S. Technical Conference, Miami, Florida, Aug. 30-Sept. 3. (To appear in Illum. Engin., 1964 or 1965.) 43

General

1963 Nickerson, D.
LIST OF PUBLICATIONS AND REPORTS (1928 to 1964). 44

Reprinted from Textile Research Journal, Vol. XX, No. 4, April, 1950
Printed in U. S. A.

Foreign-Matter Content in Bales of Cotton Used for Grade Standards

Dorothy Nickerson

United States Department of Agriculture, Production and Marketing Administration, Cotton Branch

In 1946 color measurements were reported [1] for the U. S. official standards for grade of American upland cotton. Except in official annual reports, there have been no reports made of the foreign matter in grade standards, or in cottons classed against those standards, although a scale based on such measurements is used for comparison of test results obtained with the Shirley Analyzer that are made as a part of our Cotton Testing Service [3, 6].

During the 1946 International Cotton Grade Standards Conference there was considerable discussion by manufacturers and others which indicated a widespread belief that the Government had increased the amount of trash in the 1946 standards for some or all of the grades. Since there had been no intention of making any change in the foreign-matter content of the grades, the color laboratory (after the conference) obtained samples of the standards bales in order to check on their foreign-matter content. Although it is the surface of the sample in the grade-standards boxes that represents the grade, nevertheless it was felt that a measurement and comparison of foreign matter in the bales would indicate whether there had been any inadvertent change in the standards between 1936 and 1946.

This report includes a study of the foreign-matter content of the bales used in preparing standards for the 1936 and 1946 International Cotton Grade Standards Conferences.

Method of Analysis

In order to supply a record of the foreign-matter content of cotton grade standards, it has been customary for many years to photograph each standards box after it is passed by the Review Committee and to place a full-scale copy of this photograph in the cover of each box. Photographs are compared for leaf with a photograph of the original or duplicate standard which is used as a guide in the preparation of boxes of similar grade. Although these photographs provide a record which can be checked, they do not make it easy to report a statistical measure of trash content, and measurements obtained with the Shirley Analyzer have therefore been used for trash analyses.

The Shirley Analyzer [2] is a laboratory instrument which was developed at the Shirley Institute, Manchester, England, which provides an effective means for making an almost complete separation of cotton lint and trash, with a minimum of fiber loss. After the separation the weight of lint fed into the machine, the weight of lint delivered, the weight of visible foreign matter, and the percentage of nonlint (calculated from the total of visible and invisible losses) are reported. Although the figures are based on weight determinations and although they do not take into consideration the nature of trash, which is sometimes as important as weight in determining grade, they are the best figures obtainable for providing a measure of trash content.

Nonlint removed by the Shirley Analyzer is distinguished from the total picker and card waste of the manufacturing processes by the fact that practically no fiber is included as it is in the usual waste from mill cleaning machines. Therefore, picker and card waste results reported on a basis of spinning tests are not expected to agree with results obtained with the Shirley Analyzer.

Procedure

In 1936 the cotton grade standards were revised. After approval of the grade standards by the delegates to the International Universal Cotton Standards Conference of 1936 [4], samples of each of the bales used in these standards were analyzed by means of the Shirley Analyzer. Immediately after the 1946 conference [5] similar analyses were made on bales used in preparing the 1946 standards in order to

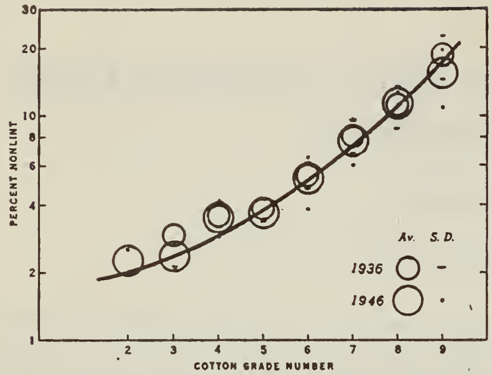


FIG. 1. *Average percent of nonlint in bales used for the 1936 and 1946 white grade standards.*

check on the agreement of 1946 standards bales with those of 1936.

Results

The agreement in percentage of trash content between the 1936 and 1946 standards bales for the same grades seems unusually good. Results are shown in Figure 1. The small circles represent 1936 averages of measurements for the bales in each grade; the bar represents the variation around this average, as measured by the standard deviation. The larger circles represent 1946 averages, and the dots represent the variation of trash content in individual bales of each grade. The relationship is not a straight line when plotted on a logarithmic scale, as was thought at first, but a smooth curve can be fitted to the data. Table I gives the nonlint contents for these two sets of standards bales and a grade conversion scale based on an average smoothed curve. For samples that are normal for color, leaf, and trash content, this conversion table can be used to give an equivalent-grade, based on measurements of trash content.

TABLE I. PERCENTAGE OF NONLINT* FOR BALES USED IN PREPARING COTTON GRADE STANDARDS

White grades No.	1936 standards bales Av.	1936 standards bales S.D.	1946 standards bales Av.	1946 standards bales S.D.	From smoothed curve
2			2.26	±0.26	2.0
3	2.94	±0.83	2.38	±0.29	2.4
4	3.63	±0.44	3.51	±0.67	2.9
5	3.83	±0.45	3.69	±0.15	3.7
6	5.35	±0.73	5.12	±1.32	5.1
7	8.08	±1.37	7.71	±1.74	7.6
8	11.03	±2.25	11.25	±1.44	11.0
9	18.64	±4.13	15.17	±4.20	17.0

* Determinations made with the Shirley Analyzer.

Literature Cited

1. Nickerson, D., Color Measurement of Standards for Grades of. Cotton, TEXTILE RESEARCH JOURNAL **16**, 441–9 (Sept. 1946).
2. Pfeiffenberger, G. W., The Shirley Analyzer, TEXTILE RESEARCH **14**, 50–4 (Feb. 1944).
3. U. S. Dept. of Agriculture (P.M.A., Cotton Branch), Regulations Governing Cotton Fiber and Spinning Tests Under the Act of April 7, 1941.
4. U. S. Dept. of Agriculture, Developments in Cotton Standardization and Related Activities, Service and Regulatory Announcements No. 163, Aug. 1942, 26 pp.
5. U. S. Dept. of Agriculture, Further Developments in Cotton Standardization and Related Activities, Service and Regulatory Announcements No. 165 (P.M.A.), Nov. 1947, 35 pp.
6. U. S. Dept. of Agriculture (P.M.A., Cotton Branch), Cotton Testing Service, Oct. 1949, pp. 1–29 (processed).

(Manuscript received December 28, 1949.)

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration
Cotton Branch

COLOR MEASUREMENTS OF COTTON

Preliminary Report on Application of New Automatic Cotton Colorimeter

Washington, D. C.
April 1950

CONTENTS

ACKNOWLEDGMENT

The work reported here is a part of the research program under the direction of John W. Wright, Chief, Research and Testing Division, Cotton Branch. Special thanks are due to Richard S. Hunter and members of the Henry A. Gardner Laboratory for their cooperation in the development of the instrument, and to H. C. Slade and R.L. Kause, and others of the Standards and Futures Division, Cotton Branch, for their cooperation in applying the instrument to problems relating to cotton grade standardization.

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration
Cotton Branch

COLOR MEASUREMENTS OF COTTON

Preliminary Report on Application of New Automatic Cotton Colorimeter

By Dorothy Nickerson, Cotton Technologist

INTRODUCTION

Color measurements of raw cotton have been made in the United States Department of Agriculture since 1927. The Munsell color notation was adopted as a means of specification since the color steps in its scales of hue, value, and chroma are visually equidistantly spaced, and as a consequence, color measurements expressed in these terms may be interpreted by the cotton man in terms that relate to his own color experience. Instruments were built about 1930 to employ the very simple, direct, visual method of disk colorimetry. 1/

Since 1927 there have been remarkable advances in the science of colorimetry. In 1931 international standards were adopted for a standard observer, standard illuminants, a standard method for illuminating and viewing a sample, and a standard coordinate system for expressing results of color measurements. These have made it possible to standardize and interrelate methods of color measurement and specification (4). 2/ They have, in fact, made it possible to specify the characteristics of filter-photocell combinations that would allow color to be measured in terms of what would be seen by a standard observer under specified conditions of illumination, viewing, and background.

Electronic methods have been successfully employed in commercially available spectrophotometers since 1927, but the problems involved in producing satisfactory automatic colorimeters are much harder to solve. For many years several types of instruments employing filters and photocells have been available but it was not until 1942 that a detailed discussion of the problem was published by R. S. Hunter (1), then associated with the colorimetry section of the National Bureau of Standards.

1/ See Appendix and references for details of methods and instruments.
2/ Figures in parentheses refer to Literature Cited, p. 13.

Meanwhile, in the laboratories of the Cotton Branch a filter-photocell scanning device was developed. 3/ This device operates successfully to scan the surface of a cotton sample by means of a very small spot (1/64 inch in diameter). The resulting data are so complex even for single samples that at present the instrument is useful only as a research tool. Its development pointed the way, however, to a more simply constructed instrument that could be based on generally similar principles but one that would be useful in the classing room as well as in the research laboratory.

After the 1946 International Grade Standards Conference it became increasingly apparent that a device of this sort would be of considerable practical use as a classing aid, and plans were initiated to develop a photoelectric direct-reading device for measuring the color of cotton. Before specifications were completed it was learned that R. S. Hunter had designed a Color and Color-Difference Meter. A study of this instrument proved that its principles were adaptable to the Department's initial purpose. This instrument — an improved colorimeter based on earlier work with the Hunter Multipurpose Reflectometer — reads directly in terms of three color coordinates, R_d (Percent Reflectance), ±"a" (red-green), and ±"b" (yellow-blue). Although these coordinates differ from the visual scales of the Munsell notation, enough colorimetric information is now available so that the two systems can be interrelated (6). In fact, for the range of cotton colors a plot of the cotton grade standards in terms of Hunter's R_d and +b appear quite similar to a plot of the same material in terms of Munsell value and chroma. For laboratory use this instrument proved to be entirely satisfactory for making color measurements that are in the range of cotton colors. The ultimate purpose, however, was to supply a fully automatic, self-standardizing instrument that could be operated successfully by classers in any cotton classing room. Specifications for such an instrument were drawn up, and it was manufactured and delivered for use in January 1950. This colorimeter was described in March 1950 by Nickerson, Hunter, and Powell before the Optical Society of America (8).

Photographs of this new, automatic, self-standardizing instrument are shown in figures 1 and 2. The instrument was in operation when the photograph shown as figure 1 was taken. A cotton sample is in position over the exposure window of the instrument, the operator has just stepped on the foot switch, and the indicators have moved to a position of balance. A typical use of the instrument is shown in figure 2 in which several members of the Cotton Branch are shown going over color measurements in order to make bale selections for cotton grade standards. The exposure window and the sheet for recording color measurements may be seen in figure 3. Figure 3 is a top view of the colorimeter. It shows the placement of the cotton sample. The

---

3/ By Clarence M. Asbill and Dorothy Nickerson about 1941-42. No report on this device has been published.

Figure 1. — Recording color of cotton on new automatic cotton colorimeter.

Figure 2. — Members of the Cotton Branch use new automatic cotton colorimeter in making selections of bales for use in cotton grade standards. Note exposure window where sample is to be placed for measurement.

measurement of color is recorded by the position of indicators that move directly under the cotton scale diagram shown on the translucent glass panel in the center of the instrument. One indicator moves in a vertical direction to indicate change in reflectance of the sample (R_d), the other indicator moves in a horizontal direction to indicate change in degree of yellowness of the cotton (+b).

The cotton grade diagram used on the instrument is based on measurements of standards passed at the 1946 International Grade Standards Conference and in effect since August 1, 1947 (9).

Figure 3. — Top view of Nickerson-Hunter Cotton Colorimeter with cotton sample in place over viewing window of instrument. Result is shown by indicators that move under center translucent panel on which color positions of cotton grade standards are indicated.

The relation of grade standards as they have been changed from time to time is shown on the 4-part diagram of figure 4. The color measurements of three of the four sections of this diagram are shown in terms of value and chroma; the fourth is in terms of Hunter's coordinates R_d, +b. As may be noted, when color measurements of cotton grade standards were made in 1931, the high grades were very creamy, and there were standards for blue and yellow stained cottons. In 1935 the grade standards were modified. Details of the color changes

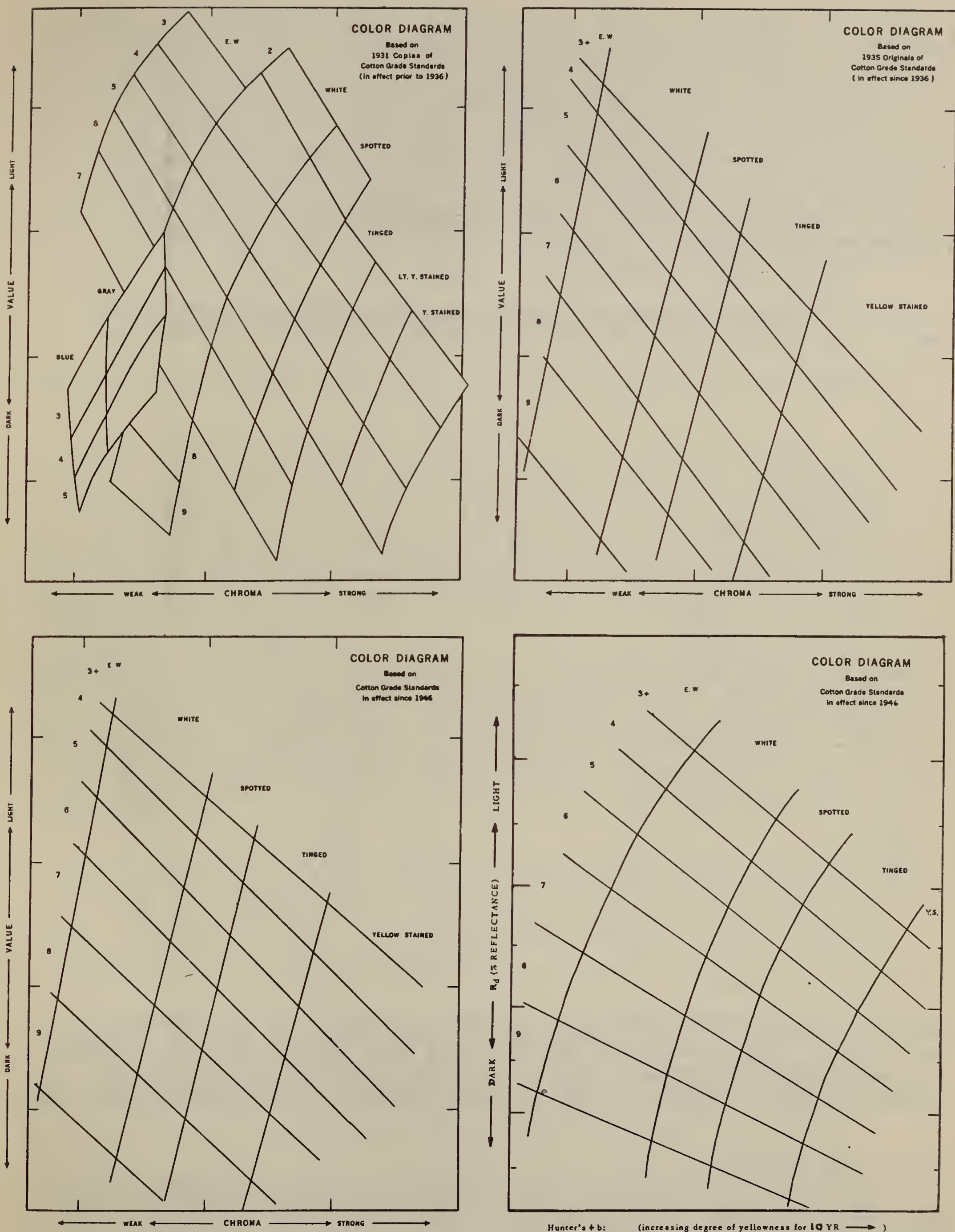
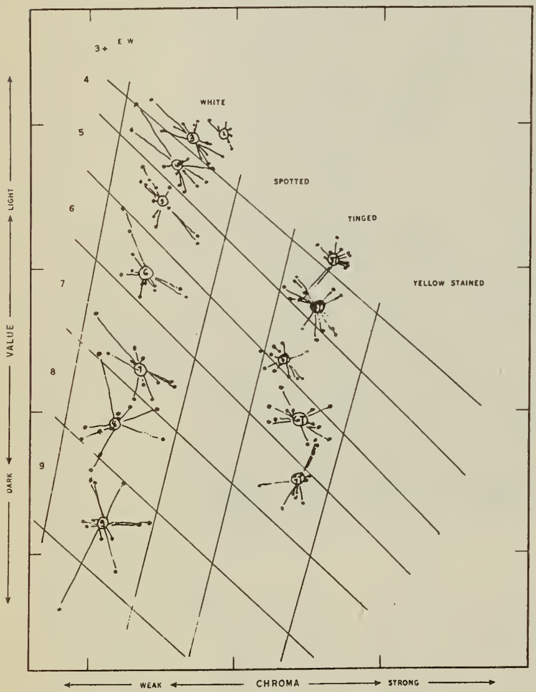


Figure 4. — COLOR DIAGRAMS FOR GRADE STANDARDS SINCE 1931. The upper left diagram is based on 1931 measurements of grade standards; the upper right on changed standards in 1935. Both diagrams are in terms of Munsell value and chroma. The lower diagrams represent grades adopted in 1946, the one on the left in terms of value and chroma, the one on the right in terms of Hunter's R_d and $+b$.

involved were described in 1946 in the Textile Research Journal (3). The change from prior standards is shown by a comparison of the two upper diagrams of figure 4. In 1946 new standards were again adopted. At the 1946 conference, in spite of some opinion to the contrary there was no change intended in the white standards, 4/ but the standards for the tinged grades were raised slightly, thus necessitating a change in the color diagram after this conference. The two lower parts of figure 4 contain diagrams that represent the 1946 standards, the diagram to the left being in terms of value and chroma measurements made on the disk colorimeter, the diagram to the right in terms of R_d, +b measurements of the automatic cotton colorimeter.

To show the relation between the old and new measurements in more detail, figure 5 has been prepared. On each diagram measurements of the detailed



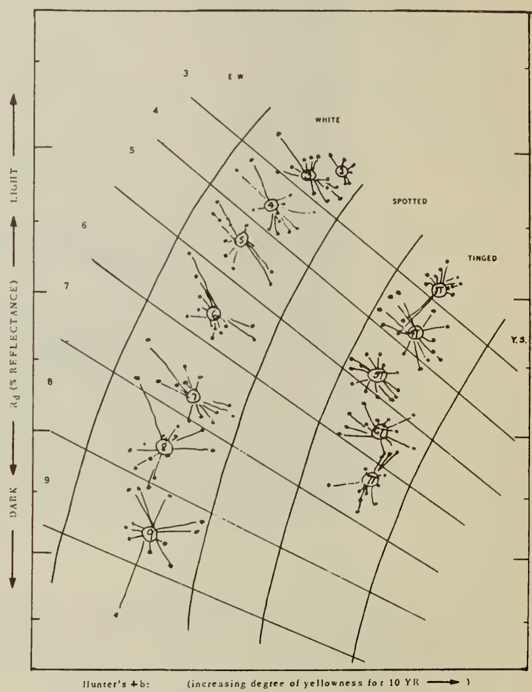


Figure 5. — Color of 12 samples in each box is related to the average for each grade. Measurements to the left were made in 1946 by disk colorimetry and plotted for Munsell value and chroma. The same information is shown in terms of Hunter R_d and +b color factors in the diagram to the right.

4/ There is considerable color change, particularly in high grades, when cotton is stored for long periods. The objective in 1946 was to put up 1946 boxes as they appeared in 1936 — not as the 1936 or 1939 key boxes appeared in 1946, after having changed in color during storage between conferences. See (9).

samples, 12 to each grade box, are indicated. Those in terms of the Munsell diagram are taken directly from measurements made in 1946 on a representative series of boxes passed at the 1946 conference. The diagram to the left represents what these samples would have been expected to measure on the photoelectric instrument had it been available in 1946. To make the (R_d, +b)-diagram, full sets of grade standards were measured on the automatic instrument as soon as it was delivered, a duplicate series of measurements being made at the same time on the disk instrument. By pairing these measurements and working out a grade diagram for the (R_d, +b)-scale that would show a similar relation to that of measurements on the disk instrument, it was possible to prepare the chart shown.

MEASUREMENT OF COTTONS FOR USE AS GRADE STANDARDS

Grade of cotton depends upon color of fiber, amount and kind of foreign matter, and roughness or smoothness of ginning preparation.

The U. S. Standards for grade of American upland cotton, known as Universal Standards, are accepted and used the world over. In this country their use is mandatory for the sale of cotton that is not sold on private type or actual sample. In 1950 there are 33 grades for upland cotton in effect, 13 of which are represented in physical form. Each grade is put up in a black box, 20 by 20 inches, containing 12 samples to represent the range of the grade (a typical box is shown in lower right of fig. 2).

Early in the cotton color-measurement work statistical correlations were made of hue, value, and chroma measurements of the white cotton standards against their grade number (2). These correlations were as high as 98 percent, the value and chroma factors contributing about equally to the correlation but hue not at all. On the basis of these correlations, diagrams for plotting the color of cotton since that time have been two-dimensional.

Color measurements of cotton samples are made on the composite appearance of the sample; in other words, the color measurement represents an average of the contribution made to the color of a sample by the color of fiber, the amount, color, and kind of foreign matter, and the roughness or smoothness of its ginning preparation.

Since the combination of color of lint and of foreign matter (7) in cottons used in the grade standards fits a pattern of what is normal for each grade, it could be expected that a correlation of the amount of foreign matter against grade would be about as high as that found for color measurements. In other words, for cottons already carefully selected for use in the standards, measurements of either the color or the amount of foreign matter in a sample would allow an accurate prediction of grade for all but a very few cases. This should be true whether color measurements are made by one method or by another. Occasionally, as may be seen from an inspection of figure 5, a sample in

the standards box may be outside the color limits that are drawn on the basis of the average of each grade, but for such a sample it is known that poor color of lint is balanced by less foreign matter in the sample.

In measurements with the disk instrument the sample is placed in the instrument so that its surface is viewed in the same condition as by the classer. If the sample is rough, shadows will reduce the color reading. As an example of this, it was found possible to get slight yet consistent differences for paired samples of cotton that were ginned with tight and loose seed roll conditions.

On the Hunter Color and Color-Difference Meter referred to previously one of the first things studied was the effect of pressing the cotton sample against a glass window. Obviously, the appearance of a sample under pressure is not the same as when it is fluffed out in a hand sample. The question is whether the same relation of color differences will be found between the color of samples under pressure and without pressure. Results for the 156 samples in the 13 grades of cotton put up in physical form showed that measurements made behind glass give a picture of relative color between samples that is quite like that of the color relation between samples measured without pressure. Although minor variations may be found when a very thorough study of this question is made with a wide variety of controlled samples, the tests already completed show that it will not be a factor of major significance. However, if measurements are to be repeated within a reasonable tolerance it is important that samples be prepared in the same manner and measured under the same pressure.

Because the grade standards are put up in a specific manner, out of cottons that already have been selected visually as a good match in color, leaf, and preparation for each position in the grade boxes, and because they are put up in cartons holding about the same amount of cotton for each sample it has been possible to make immediate application of the new instrument to the cotton grade standards work. The grade diagram, based on measurements of cottons so selected and measured, should apply to other cottons that may be similarly selected and similarly prepared for measurement.

In the determinations completed to date, and on which the diagram in figure 5 is based, the cottons were measured in standards cartons placed over the instrument window the long way of the carton. This is necessary because cottons prepared for the standards are rolled and smoothed, the side edges being rolled under the sample as it is held the long way. The sample is then placed in the carton the long way and the edges tucked in at the top and bottom. As a consequence, samples prepared for the standards have a sort of "grain," and to avoid measurements that differ because of this, all samples are presented to the instrument in the same direction.

In preparation for use in the 1950 grade standards, after a bale was selected visually and by instrument to be the best available for a wanted position in any grade, every sample put up for use in a single position was placed in cartons, leafed like the photograph of the guide standard, and then measured for color. Preparation, particularly in grades Strict Good Middling and Good Middling, is an important factor affecting the color measurements. There is very little difference in lightness of color for cottons above Strict Middling, but very smooth preparation of a sample can make it appear to read slightly higher in color than when normal in preparation. If a sample is remeasured later with the surface in a different condition, the measurement will also differ to accord with the altered surface preparation. As may be inferred, all the grade factors must be taken into consideration and each prepared to represent the standards correctly before a sample is measured for use in the grade standards.

In figure 6 the results for several typical positions are shown. The large open circle in each grade block represents the average of the grade in 1946. The arrow from that center points to the position

Figure 6. — Color measurements of samples put up to match several typical positions in the grade standards. Open circles represent the average of 1946 standards for grades noted; arrows point to color of sample for position the bale is intended to match; dots represent measurements of accepted samples; crosses represent rejected samples. Scatter of dots and crosses represent amount of color variation of samples taken from the same bale. Note smaller scatter for high grades than for low grades.

which is to be matched. The dots represent samples accepted as within a reasonable tolerance for the position; crosses represent samples that were considered too far off to be acceptable. Although it was known previously that even for uniform bales there are differences between samples from the same bale, this is the first time there has been any large amount of data to demonstrate the degree of color variation that exists between samples from such bales.

The size of the carton in the standards box is 5 by 6 inches. The size of sample measured on the disk instrument is about 4 inches in diameter. On the new instrument it is about 2-1/2 by 3-1/2 inches. This means that unless the face of the sample is masked off to this size the classer sees the edges around the sample in a grade standards carton, and if the sample is uneven in trash, spots, or in distribution of background color, it may seem to him that measurement of a larger face would be more valid. One look at the distribution of measurements shown in figure 6 should make it clear that while a slightly larger sample area might be more satisfactory for a particular sample, such a sample would no more surely represent the average of the bale than the one now measured. The question of the proper size of sample resolves itself into one of practical tolerances. One could use elaborate mixing devices, then chop up a selected portion of the fibers, and pack them to a specified density in a glass cell of specified size, or one could make measurements at several places on a single sample and take the average result for an answer. But would all of this additional care provide a measurement of any more practical significance than a single measurement of the sample as now taken? For some purposes it may be an advantage to do a special measurement job, but on the basis of experience with cotton color measurement it seems adequate to set tolerances for present standards on the basis of the results shown in figure 6. If closer tolerances are required, the bale selection job would become even more difficult than at present, and the percentage of rejections would become very high.

MEASUREMENT OF COTTONS OTHER THAN THOSE USED IN THE GRADE STANDARDS

This question of tolerance in measurements is not the only one that must be considered. It has been possible to make immediate use of the new instrument for such a selected series of cottons as those prepared for the grade standards because these cottons already are carefully selected to represent a normal combination of color, leaf, and preparation for the grade each represents. The amount of cotton put into each carton is about the same, and the samples are measured in the cartons, a given weight being applied at the time of measurement.

For such samples as these, the colorimeter becomes almost a "grader." Note the <u>almost</u>. For it should be kept in mind that this instrument is intended as an aid to the classer; it cannot replace him. And the reason that it cannot is that the instrument sees only one thing. It sees the average color of whatever appears on the face of the sample placed over its sample window. If the conditions under which a sample

is tested are not the same each time, the measurements should not be compared. The instrument reports what it sees; if a sample is measured once with no weight, and the next time with 1 pound, then with 3 and 4 pounds, the color answer will hold only for the condition under which it was measured. The most efficient weight and sample size to be used in general cotton color measurements have not yet been determined, but since the amount of cotton in the average grade standards carton is a convenient handful, and since so much work in the Grade Standards Laboratory must be done on a sample of this size, it seems likely that a sample somewhat near this size will be made standard.

A weight of slightly more than 5 pounds has been used in these first few months of work. This was set because it seemed to be enough so that the addition of a pound or so made little difference in the result. Perhaps if another 5 or 10 pounds were used it would make a difference, but lifting a weight of that size each time a sample is to be measured is not satisfactory, except as a temporary expedient.

Aside from the question of a standardized method of making sample measurements, there are other factors that must be taken into consideration before one should attempt to judge the grade on a basis of color measurements. The instrument — whether this one or any other — cannot tell whether the color it reads is the result of spots, of amount or color of foreign matter, or of general background color. All manner of combinations could be made up that the instrument would report to have the same average color, but which a classer would immediately put into the correct color classification. For example, a classer can see a given amount of leaf in a sample whether it be light or dark in color. He can differentiate a gray cotton from a white or an extra white, and once he does identify a sample as gray and not white the instrument then can help him to classify it into the correct grade of gray if a diagram for gray standards is prepared for his use.

The same thing is true of spotted cottons. There may be so little spot in some samples that the instrument measurement will show the same average color as for a white grade. Yet the classer would see the "light spot," and with the instrument soon could learn to place it always in the same grade of light spot. Enough tests must be made in the laboratory on cottons of this kind to make up diagrams adaptable to such cottons. Tests must be made on cottons from different areas, for while the grade standards apply to all upland cottons, the extreme range of whiteness in cottons such as are classed "white" in Mississippi and Arkansas are not covered in the boxes nor the range of the extremely white, bright cottons of the far West, many of which are extra white. With an automatic instrument it should be possible to maintain more constant interpretations of applicable grades for samples not represented in the grade boxes.

With mechanical harvesting coming more and more into use the relations of color, leaf, and preparation normal for the present grade standards may no longer hold for large portions of the crop. There remains the necessity to study such samples in sufficient quantities to provide adequate data for the development of suitable diagrams for aiding the classer to determine consistent grades for such cottons that will relate them to the present grade standards.

Already, from studies of cleaning methods (5), something is known of the color and trash relations in cleaned and uncleaned samples. But former studies, even though accepted, often may have seemed somewhat academic because measurements were made on a disk instrument that seemed not too practical to a cotton man. With the automatic direct-reading instrument now available to him, he can see for himself how the color of his samples measures. Intelligent use of this instrument in the future should enable many classers to equal the results of the few who have been expert in assessing small cotton color differences in the past.

SUMMARY

Measurements of cotton color have been made in the laboratories of the United States Department of Agriculture for more than 20 years. These have provided a fund of background information on color of cotton, of the grade standards, and of cottons differing from those used in the grade standards. Such data have been useful in the laboratory. Now, however, a new automatic cotton colorimeter has been developed that is intended as an aid in the classing room.

There are many applications of this new instrument to cotton color that still need to be studied. On the basis of information obtained by previous methods, there are, however, certain applications that can be made immediately and it is to describe these applications, and to warn of interpretations that cannot be made correctly without a knowledge of the various factors that make up the grade of cotton, that this preliminary report has been prepared. In the hands of an intelligent cotton classer with an elementary knowledge of the factors of color, the new instrument can be valuable in helping to keep classification consistently in line within a single organization as well as in relation to whatever grade standards may be in effect.

For cottons that are within the range of the samples in the grade standards boxes and similar to them in combinations of color of lint, color and quantity of foreign matter, and ginning preparation, the colorimeter becomes essentially a "grader." But for samples not like the standards in the relations of these three grade factors — perhaps more spotted, or with a combination of more leaf and better color, or of poor color and little leaf, as in the gray cottons, or even the same amount of leaf but unusual in color, as very light, or possibly grassy — in all such cases as these the color indicated by the

instrument must be interpreted in relation to an evaluation based on a suitable weighting of the separate factors. The man who knows cotton can do this and thus make use of the instrument as an aid to cotton grading; the man who does not know cotton should strictly limit his interpretation to that of the average color of the sample. In the one case the instrument can become an "assistant grader," in the other it should remain a "colorimeter."

LITERATURE CITED

(1) Hunter, R. S.
1942. Photoelectric Tristimulus Colorimetry with Three Filters. Optical Soc. Amer. Jour., 32:509-538, illus. [U. S.] Natl. Bur. Standards Circular (C429), illus.

(2) Nickerson, D.
1946. Color Measurement and Its Application to the Grading of Agricultural Products. U. S. Dept. Agr. Misc. Pub. 580, 62 pp., illus.

(3) ______
1946. Color Measurement of Standards for Grades of Cotton. Textile Res. Jour., 16:441-449, illus.

(4) ______
1947. Interrelation of Color Specifications. U. S. Dept. Agr., 45 pp., illus. (Processed.) Paper Trade Jour. 125:153-171, illus.

(5) ______
1947. Effect of Cleaning on Grade and Color of Cotton. U. S. Dept. Agr., 26 pp., illus. (Processed.)

(6) ______
1950. Munsell Renotations Used to Study Color Space of Hunter and Adams. Optical Soc. Amer. Jour. 40:85-88, illus.

(7) ______
1950. Foreign Matter Content in Bales of Cotton Used for Grade Standards. Textile Res. Jour. 20:277-278, illus.

(8) ______, Hunter, R. S., and Powell, M. G.
1950. New Automatic Colorimeter for Cotton. U. S. Dept. Agr., 8 pp., illus. (Processed.)

(9) United States Department of Agriculture
1942. Further Developments in Cotton Standardization and Related Activities. Service and Regulatory Announcements No. 165 (PMA), 35 pp.

APPENDIX

Munsell Specification. The Munsell method of color notation was developed in the United States in the early part of this century. It may be used directly by comparison to samples on color charts or it may be used indirectly by converting I.C.I. 5/ data into Munsell terms. In the Munsell notation, color is expressed in units of visual difference of the three psychological attributes: Hue, lightness, and saturation. By this method results of color measurement are expressed in terms of color order rather than color mixture, and allow an interpretation of results in terms of the visual qualities known in the Munsell system as hue, value, and chroma.

Hue is that attribute of a color perception that determines whether it is red, yellow, green, blue, purple, or the like. Value is the expression of reflectance of an object color on a scale giving approximately uniform perceptual steps under usual conditions of observation. Chroma is the expression of the degree of departure of an object color from the nearest achromatic color (gray); under ordinary observing conditions Munsell chroma of a specimen correlates well with the saturation of the color perceived to belong to the specimen.

The relationship of the three color attributes can be best described in terms of a three-dimensional color space in which all discriminable colors are conceived to be arranged so that neighboring colors differ from one another in each of the three attributes by just noticeable degrees. The numerical scales of the Munsell system, for normal conditions of color matching, bear approximately the following relation to each other when chroma is at /5: 1 Value step = 2 chroma steps = 3 hue steps.

The notation of the Munsell system is written H V/C, as 5R 4/10 which reads "red, four value, ten chroma," or "red four-ten." Because the scales are decimal the notation can be expressed in as small a difference as it is possible to identify. For cotton measurements, value is carried to two decimal places, and chroma to one decimal place in order to express the small color differences in cotton color that are represented in the grade standards. For further details, reference may be made to the discussion and literature citations of (2) or to a brief paper on "Color and Its Description" in the February 1948 Bulletin of the American Ceramic Society (27:47-55).

The relation of the Munsell system to the I.C.I. system is fully covered in a series of papers that appear in the July 1943 Journal of the Optical Society of America. For historical discussions there are several reports in the December 1940 number of the same journal.

5/ These initials refer to the International Commission on Illumination, the group under which international standards were adopted for colorimetry.

Disk Colorimetry. Disk colorimetry is a very simple and fundamentally sound method of additive colorimetry, suggested years ago by Clerk Maxwell. By the use of Maxwell disks — cut with a radial slit so that several may be slipped together with portions of each visible — and a motor on which to spin them at a speed great enough so that there is no flicker, any color that lies in the color solid within the volumes intermediate to the colors of the disks used, may be matched. Precision in matching can be self-taught. An observer has either to make many measurements and use an average, or reduce his scatter to a minimum and use fewer measurements. He can decide for himself when he is able regularly to repeat his readings to a tolerance that is satisfactory for the studies he wishes to make.

Instruments for use in disk colorimetry were developed for use in the United States Department of Agriculture laboratories in the early 1930's and have been used since that time. Spinning optical parts were incorporated into these instruments in order to avoid spinning either the sample or the disks. A handbook on the method of disk colorimetry was published in 1946 (2).

I.C.I. Specification. By the I.C.I. method of color notation, results of color measurements are reduced into terms of the standard observer and coordinate system of colorimetry adopted in 1931 by the International Commission on Illumination. The data are expressed as the absolute (X, Y, Z) and fractional (x, y, z) amounts of three imaginary red, green, and blue lights necessary for an imaginary standard observer to match a given sample under a given illuminant. The I.C.I. Y function is set to represent the luminosity, and I.C.I. data are therefore often expressed as Y for luminous reflectance, and as (x, y) for plotting on an (x, y)-mixture diagram. An illuminant of some sort must be assumed before calculation of I.C.I. data, and that illuminant thereafter becomes the reference point for the data. The spacing on an I.C.I. (x, y)-diagram has little relation to equal color-sense intervals.

Use of I.C.I. data makes it possible to interrelate results of measurements by any instrument or method that has been standardized in terms of I.C.I. The relation of Munsell to I.C.I. has been fully reported in (2) and its references.

Photoelectric Tristimulus Colorimetry. As reported by Hunter (1) the term "photoelectric colorimetry" may be employed either to designate tristimulus colorimetry or abridged spectrophotometry. For the purposes of the work discussed in this report it is concerned with tristimulus colorimetry in which it is desired to find a source-filter-photocell combination using three or more filters which combine to provide spectral characteristics that duplicate I.C.I. conditions for the standard observer under specified conditions of observation (for usual work these include average background, daylight illumination).

No one has yet duplicated perfectly the desired combinations but several investigators have obtained combinations suitable for satisfactorily measuring color differences between samples that are spectrally similar.

Any instrument that is to measure color differences as small as those recognized daily by trained inspectors or classers in many lines of commercial color work must have high precision.

The Hunter type of colorimeter that is used as a basis for the automatic instrument discussed in this report employs photocells and three filters — amber, green, and blue — which approach but do not match the spectral distribution curves for I.C.I. (X, Y, Z)-data using daylight for the illuminant as expressed by I.C.I. Illuminant C.

<u>Hunter (R_d, a, b)-coordinates.</u> As reported in (<u>1</u>) the source-cell combinations using the amber, green, and blue filters selected for use by Hunter result in the following approximations for I.C.I. (X, Y, Z):

$$X \doteq 0.80A + 0.18B$$
$$Y \doteq 1.00G$$
$$Z \doteq 1.18B$$

These equations are only approximate because the combinations differ somewhat spectrally from the desired I.C.I. data. As far as is known no better combinations have yet been produced.

Because I.C.I. coordinates do not supply a plot representing uniform chromaticity, Hunter very early developed a new relation based on photoelectric tristimulus results that allows color to be plotted to show more uniform spacing than in the I.C.I. diagrams. The early Hunter chromaticity plots were for α , β on a basis of the following equations:

$$\alpha = \frac{A - G}{A + 2G + B}$$

$$\beta = \frac{0.4(G - B)}{A + 2G + B}$$

Later, in developing a direct-reading instrument the filter combinations were adjusted so that subtractions of the light through the filters are made within the instrument and thus avoid mathematical computations by the operator of the instrument. If instrument combinations could have been made that would result in readings in terms of the color attributes of hue, value, and chroma this would have been done. As it is, the best approximation to uniform spacing that the instrument facilities allow, was adopted. For lightness, either a direct-reading of luminous reflectance, R_d, is used, or an L reading, which is related to R_d by a factor f_Y,<u>6</u>/

<u>6</u>/ $f_Y = 0.51 \left[(21 + 20Y)/(1 + 20Y)\right]$

is used to make the steps of the scale more uniform to the eye. If the Munsell value function could have been incorporated into the instrument it would have been used for L, but as it is, f_Y provides the closest approach to this that seems instrumentally possible at present. On the new direct-reading instrument, chromaticity is expressed in terms of the following (a, b)-coordinates:

$$a \doteq 175\, f_Y\, (1.02X - Y)$$
$$b \doteq 70\, f_Y\, (Y - 0.847Z)$$

Cartesion coordinates and an origin located at a point representing white (MgO) are used for plotting $\pm$a representing the direction of red-green, $\pm$b representing the direction of yellow-blue. The relation of Munsell hue and chroma to the Hunter (a, b)-coordinates for value 5/ is shown in figure 7.

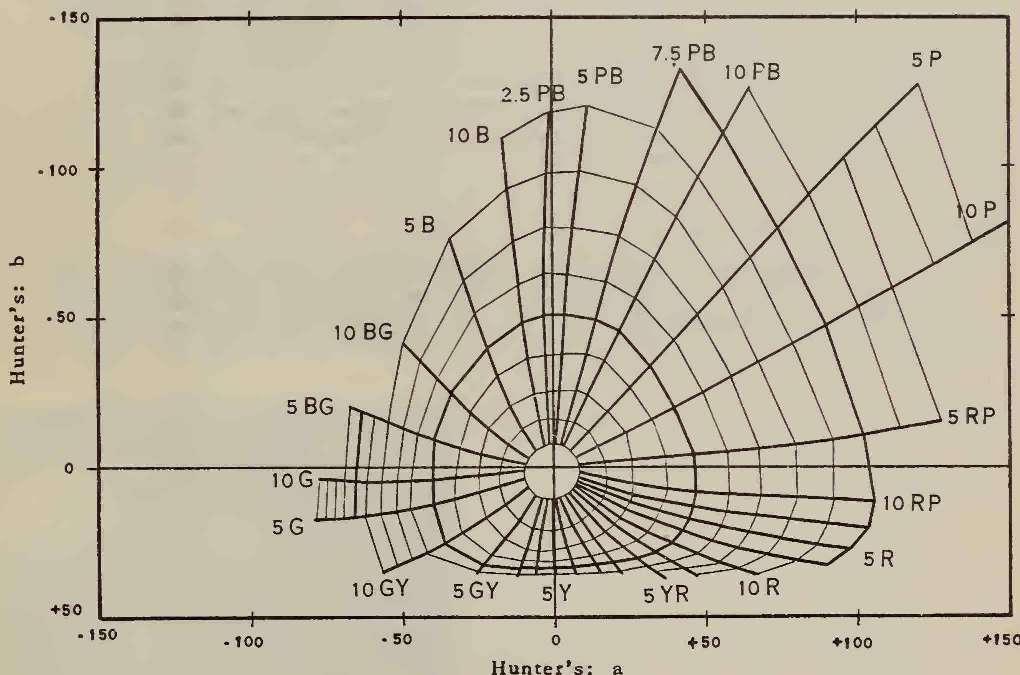


Figure 7. — Diagram showing relation of color based on Hunter (a, b)-coordinates to Munsell hue and chroma (for value 5/).

For the new automatic colorimeter the factors R_d and +b are directly measured on the instrument as indicated in the diagram to the right of figure 5. A measurement of +b relates to the degree of chroma 7/ as long as the hue of the cotton remains the same. The hue is so nearly constant for such a very large proportion of cotton that an instrument based on the two factors of R_d, +b seems adequate for all but those few samples that may be grassy (showing more green than usual) or peculiarly red stained (so that the color becomes more red than usual). Such samples can be measured, but they will not fall into line for chroma as will the cottons of constant hue.

In regard to the precision of measurements on the new automatic instrument a series of five special Munsell color samples were measured and converted to terms of R_d and +b. These cover a wide range of cotton colors. Careful spectrophotometric measurements were made on these standards by the National Bureau of Standards (reported in table 1, page 87, February 1950 Journal of the Optical Society of America). These have been used as standards on the instrument from January to April. The results of their continued measurement illustrate that the precision of this new instrument may be expected to be within 0.1 Munsell chroma step and 0.05 Munsell value step. The self-standardizing features of the instrument keep it within these limits.

7/ Constant +b represents higher chroma for dark colors than for light colors. A comparison of the two diagrams in figure 5 illustrates this relationship of +b to chroma for the range of cotton colors.

Reprinted from Journal of the Optical Society of America, Vol. 40, No. 7, 446–449, July, 1950
Printed in U. S. A.

New Automatic Colorimeter for Cotton

Dorothy Nickerson
Production and Marketing Administration, U. S. Department of Agriculture, Washington, D. C.

and

Richard S. Hunter, and Marshall G. Powell
Henry A. Gardner Laboratory, Bethesda, Maryland
(Received March 20, 1950)

This new instrument for measuring the color of cotton is based on a satisfactory application of the Hunter Color and Color-Difference Meter to problems of raw cotton measurement. It is designed to be fully automatic and self-standardizing, and graphically to show values for reflectance (R_d) and yellowness ($+b$) on a two-dimensional chart. It is self-contained in a movable cabinet, with a minimum of exposed parts. Although this particular model is limited to measurements in the range of cotton color, the principles on which it is designed are adaptable to other limited ranges of color, in either two or three dimensions, thus providing an automatic, self-standardizing small-difference colorimeter for other limited ranges of color.

COLOR measurements have been made on raw cotton as part of the preparation of cotton grade standards for many years.[1,2] In fact, as early as 1931 a disk colorimeter for such use was described before this society, with a companion discussion of color measurements in psychological terms.[3,4]

The desirability of expressing color measurements in terms related to the psychological attributes of color has been increasingly recognized by color workers in the years since 1931. Extensive work published by a subcommittee of the OSA Colorimetry Committee[5] now allows one to use the smoothed scales of the Munsell renotation space as a guide for understanding results of color measurements no matter what instrument or color space is used for their expression, providing only that it is possible to convert them either to I.C.I. or to Munsell space.[6,7]

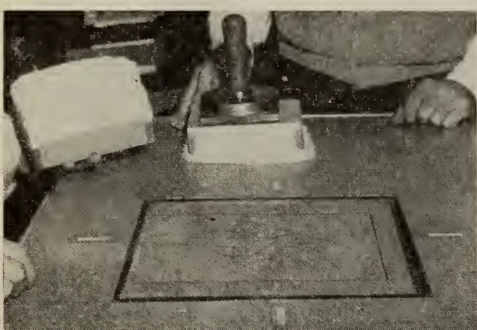


Fig. 1. Top of automatic cotton colorimeter.

Although the expression of results in color-meaningful terms has progressed in a fairly direct manner during these past years, the method of disk colorimetry, while as sound as ever in providing a direct and simple method of additive colorimetry, has a disadvantage for routine testing work in that it is visual and therefore depends somewhat upon the skill and judgment of the operator. In this modern age, measurements made by turning a few dials on a suitable photoelectric device have much more appeal for routine laboratory tests than the painstaking and tedious work of making careful visual judgments. The operation of the instrument to be described is very simple; the operator steps on a foot switch to start operation of an appropriate set of balancing motors which do the work.

The new instrument is based on a satisfactory application of the Hunter Color and Color-Difference Meter, described in 1948 before the Optical Society,[8,9] to problems of raw cotton measurement. It was found that for the limited range of cotton colors a plot of Hunter's coordinates "R_d" and "b" provided, without conversion, a chart very close to that of long-established cotton measurements plotted in terms of Munsell value and chroma.

Since the Color-Difference Meter worked so well, specifications were written for a fully automatic instrument to embody the photo-cell and filter combinations of the present instrument. The requirements were that the instrument maintain itself in standardization, and be direct reading on a two-dimensional scale, that it measure automatically, and show values graphically and simultaneously for reflectance and yellowness in a range of 40 to 90 percent R_d, and 0 to 20 units of $+b$. In this limited range it was required that the precision and accuracy of the R_d and b scale readings approximate 0.1 step or less of Munsell value and chroma scales. It was further required that the instrument be self-contained in a movable cabinet about table height,

[1] D. Nickerson, Am. Dyestuff Reporter 21, 4 (1932); Fiber and Fabric 85, 11 (1932).
[2] D. Nickerson, Textile Research J. 16, 441 (1946).
[3] D. Nickerson, J. Opt. Soc. Am. 21, 640 (1931).
[4] D. Nickerson, J. Opt. Soc. Am. 21, 643 (1931).
[5] S. M. Newhall, D. Nickerson, and D. B. Judd, J. Opt. Soc. Am. 33, 385 (1943).
[6] R. W. Burnham, J. Opt. Soc. Am. 39, 387 (1949).
[7] D. Nickerson, J. Opt. Soc. Am. 40, 85 (1950).
[8] R. S. Hunter, J. Opt. Soc. Am. 38, 661(A) (1948).
[9] R. S. Hunter, J. Opt. Soc. Am. 38, 1094(A) (1948).

that it have a minimum of exposed parts, that working parts be in the horizontal plane of the table top, and since it is intended for use in lint-filled classing rooms, that dust-absorbing gaskets be used to seal all enclosures for working parts.

Such an instrument was delivered for use in the early part of 1950. To date it has been in almost constant operation, having already measured several thousand samples of cotton in preparation for an international grade standards conference held in May. It satisfies the requirements for which it was designed.

To operate the instrument, the operator places a sample of cotton over the sample window, and steps on a foot switch. Two indicators under the chart diagram automatically move to a position of balance. Since a chart of the color of the grade standards appears on the glass panel on which the (R_d, b) scale is indicated, the operator can check against a particular position within each grade and can pass or fail a test sample by a comparison of results for that sample to the standard position indicated on the instrument chart.

Although this particular model of the instrument is limited to the range of cotton colors and measures in only two color dimensions, the principles upon which it is designed are completely adaptable to use for any other limited range of colors, in either two or all three color dimensions. For cotton a plot of R_d against $+b$ is required. For some other product a plot of $\pm a$ against $\pm b$ might be preferable, with R_d indicated on a separate scale. There are many possibilities for application of such an instrument in color inspection and grading work where a limited range of color is to be determined.

DESCRIPTION OF INSTRUMENT

The instrument was in operation when the photograph shown in Fig. 1 was taken. The sample is in position over the exposure window. Beside it is the translucent chart from which color is read by the position of the intersection of two straight-line shadows. This chart is marked with the colors of the cotton grade standards. For much of the work no record is needed since a glance at the indicator positions will tell the cotton man how the color of his sample compares to the color of the cotton grade standards which are diagrammed on the translucent screen. When records are needed, the results may be recorded in chart form as on a dot chart, with many samples for any single test plotted on one sheet. When needed, the R_d and b values may be read from the scales.

Figure 2 shows an interior view of the instrument in which the separate components are indicated by number.* The instrument consists of two parts, an exposure head, labeled 2, and a detection unit, with indicators labeled 4 and 5. These parts will be described in detail; the instrument circuit will be discussed separately.

Exposure Head

The exposure head, diagrammed in Fig. 3, is contained in a light-and-dust-tight housing, with a window

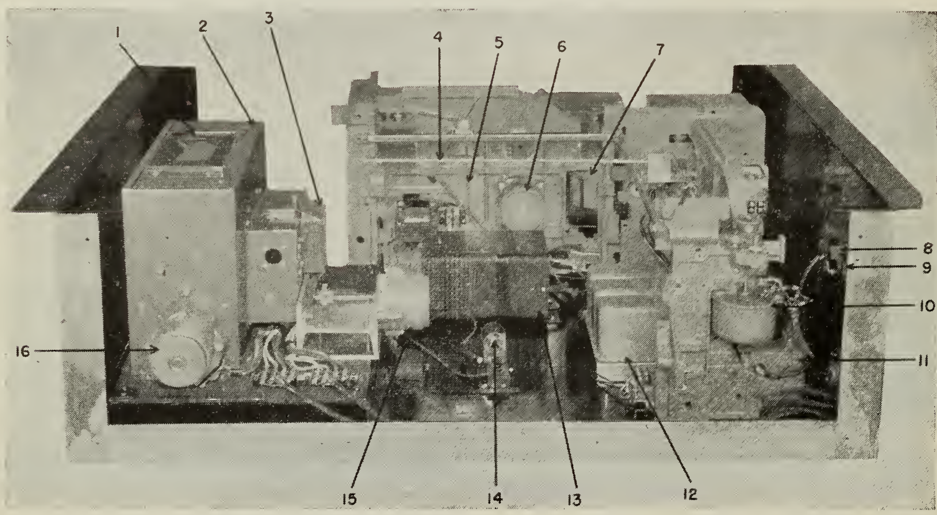


FIG. 2. Interior view of instrument, with numbers identifying components. 1, Sample area; 2, exposure head; 3, lamp guard; 4, R_d indicator; 5, b indicator; 6, R_d balancing motor; 7, R_d slide wire; 8, amplifier off-on switch; 9, lamps off-on switch; 10, b slide wire; 11, b amplifier; 12, relays; 13, CV transformer; 14, lamp for indicating scale; 15, comparison balancing motor; 16, b balancing motor.

* The labeling numbers used in Figs. 2–4 refer to identical components of the instrument.

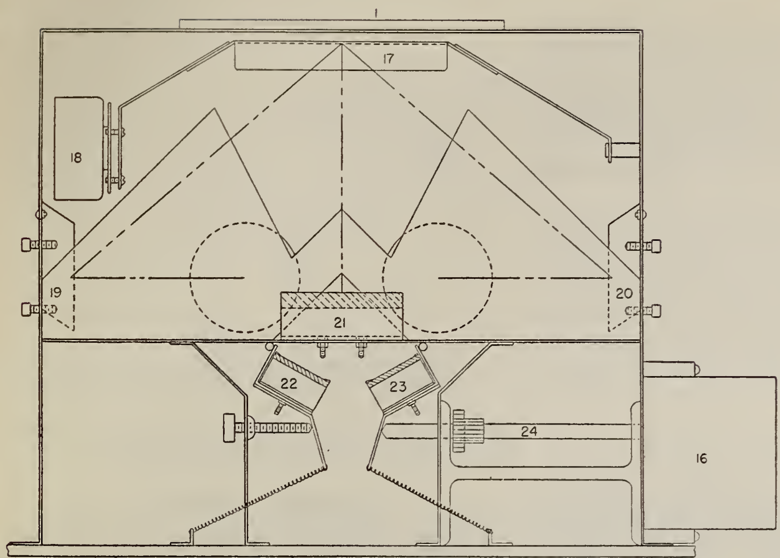


FIG. 3. Diagram of interior of exposure head, with numbers identifying components. 1, Sample area; 16, *b* balancing motor; 17, standard; 18, rotary solenoid; 19, mirror; 20, mirror; 21, photo-cells (one back, one front) blue filter; 22, photo-cell green filter; 23, photo-cell green filter; 24, micrometer adj. screw.

at the top where specimens are exposed. In this exposure head are the following:

1. A six-volt, 32 CP automobile spotlight lamp, lenses, aluminum mirrors (19, 20), and adjusting screws for directing, at 45° from opposite sides, two beams of light onto the exposure area.

2. Five barrier-layer photo-cells: (a) One comparison photo-cell with a heat-absorbing filter which views the light source, (b) a single photo-cell with green filter (22) which views the test area perpendicularly and provides the R_d current, and (c) three photo-cells connected in parallel which also view the specimen area perpendicularly, two with blue filters and one (23) with a green filter that is connected with its polarity reversed. These three photo-cells provide a residual "*b*" current that is proportional to the reflectance difference between the blue and yellow-green regions of the spectrum.

3. Two balancing motors, one (15) for adjustment of the light signal to the comparison cell, the other (16) for adjustment of the light signal to the green filter cell of the "*b*" group.

4. One internally mounted standard (17) which normally faces the R_d and "*b*" photo-cells from inside the exposure window. This standard is moved by a solenoid (18) when a specimen (at 1) is to be exposed to the photo-cells.

Detection Unit

The detection unit contains:

1. Two sensitive electronic amplifiers (one shown at 11) each with a converter for changing small d.c. signals to a.c. before amplification.

2. Two motors (one shown at 6) similar to those in the exposure head but connected in this case to slide-wire assemblies (7, 10) with moving scale indicators (4, 5). The indicators lie under a translucent sheet on which the color values are indicated.

3. Frames to hold the several assemblies.

4. Two manually operated potentiometer rheostats (at rear of instrument, not shown).

5. Constant voltage transformer (13) for the exposure head light source (under 3), relay (12), and a lamp (14) which is placed so as to cast a shadow of the indicators on the translucent colorimeter screen.

Instrument Circuit

The photo-current d.c. circuit is shown in Fig. 4. The balance method of measuring relative photo-cell currents is a modification of the Campbell and Freeth method and is similar to the circuit used in the Color-Difference Meter. When brightly illuminated the comparison photo-cell generates a constant current which is passed through two potentiometer rheostats. The two currents from the photo-cell combinations which ob-

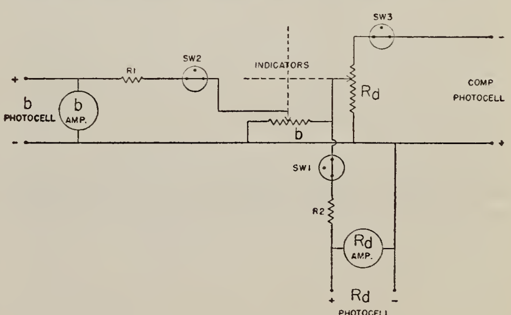


FIG. 4. Simplified d.c. measuring circuit.

serve the sample area are much smaller than this comparison current, so that each can be balanced with a small fraction of the comparison photo-cell current. The exact fraction required to balance any current from the R_d or b photo-cells is determined, respectively, by fixed resistances R_1 and R_2, and the positions of the contacts on the corresponding potentiometer rheostats b and R_d.

Any unbalance between current from the sample-viewing photo-cells and the fractional amount from the comparison photo-cell produces a potential unbalance in the corresponding amplifier input. After amplification, this current unbalance is fed to one of the balancing motors which then acts to restore balance, either by adjustment of a photo-cell position during standardization, or by adjustment of a potentiometer contact during sample measurement.

The comparison current passed through the "b" potentiometer varies with the R_d setting. This is deliberately done, as in the Color-Difference Meter, so that values of "b" measure degrees of yellowness more uniformly at all reflectance levels. The current passing through the remainder of the R_d potentiometer is also a function of the R_d setting. This causes the R_d scale of the instrument to be non-uniform in spacing, unit increments of R_d having a greater spacing at the top of the scale than at the bottom.

One performance requirement for the instrument was that it automatically maintain adjustment of the indicating scales in terms of signal outputs of the photo-cells. Since current outputs of these barrier-layer photo-cells are sensitive to temperature, and in this instrument may also vary with accumulation of dust or other extraneous factors, these current variations must be counteracted. This is done by having duplicate potentiometer circuits, only one of which is shown in Fig. 4. One is for use during standardization, the other during sample measurement. These circuits are alike in resistance values and are interchanged by simultaneous action of switches *Sw* 1, *Sw* 2, and *Sw* 3. In the normally connected circuit for standardization, contacts are set manually to scale values that represent the standard mounted in the exposure head, the amplifier output being fed to the balancing motors in the exposure head. These motors operate to adjust mechanically the positions of the photo-cells so that they provide the required relative photo-cell outputs. For sample measurement, a foot switch is depressed and one solenoid moves the internally mounted standard (17 of Fig. 3) out of the window in order to expose the test specimen. Another solenoid switches to the duplicate potentiometer circuit and switches amplifier signals to the motor-driven variable-contact potentiometer rheostats that move

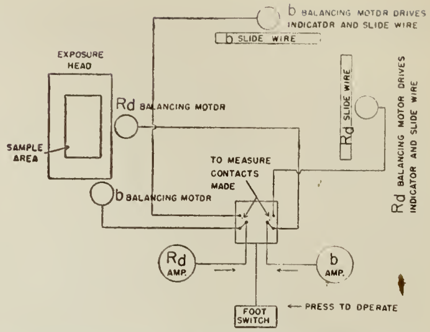


Fig. 5. Pictorial diagram of switching of amplifier output when changing from standard to sample measurement.

with indicators, thus showing the measured color values. This amplifier switching is shown in Fig. 5.

Instrument Calibration

A diagram showing the scales, based on a carefully spectrophotometered series of standard color samples, has been prepared. The intention was to use spectrophotometrically derived data for a number of standard samples in the cotton color range. Unfortunately, check measurements made on different spectrophotometers for a number of such standards, even though they were very carefully made, were so far apart in terms of the small-difference scales of this instrument that the scale for the diagram was prepared with reliance chiefly on a set of special measurements on five samples made for the purpose at the National Bureau of Standards. The data for these were reported at the last meeting of this society.[7] The other data were used as a check, a smooth line being drawn for both the R_d and b scales on the basis of general comparison to all the measurements available, leaning heavily on the special series of five made at the National Bureau of Standards. On the translucent screen the color areas occupied by each grade of cotton are indicated. In making measurements of cotton, the color of samples is referred more often to the color of the cotton grade standards than it is to the R_d and b scales of the instrument. The cotton scale-diagram is shown in Fig. 1.

As indicated before, the instrument has been in almost constant operation since its delivery in January —not by laboratory personnel, but by the classers themselves. In a surprisingly short time they have learned not only to use the instrument but to interpret the results. Thus already this new colorimeter has become the real aid to classification that it was intended to provide.

Reprinted from
TEXTILE RESEARCH JOURNAL
Vol. XXI, No. 1, January, 1951

Printed in U.S.A.

New Automatic Cotton Colorimeter for Use in Cotton Quality Specification*

Dorothy Nickerson†

United States Department of Agriculture, Production and Marketing Administration, Cotton Branch

MEASUREMENTS of cotton color made in the laboratories of the United States Department of Agriculture for more than 20 years have provided a fund of background information on color of cotton, of the grade standards, and of cottons differing from those used in the grade standards which has been useful in the laboratory. Now, however, a new automatic cotton colorimeter has been developed which is intended to serve as an aid in the classing room.

Many applications of this new instrument to cotton color still need to be studied. However, on the basis of information obtained by using previous methods, certain applications can be made immediately. The present report describes these applications, and warns of interpretations that cannot be made correctly without a knowledge of the various factors that make up the grade of cotton.

For cottons that are within the range of the samples in the grade standards and are similar to them in combinations of color of lint, in color and quantity of foreign matter, and in ginning preparation, the colorimeter becomes essentially a "grader." But for samples that are not like the standards in the relationship of these three grade factors—being perhaps more spotted; or being combined with more leaf and better color; or having poor color and a small leaf content, as, for example, in the gray cottons; or perhaps having the same amount of leaf but being unusual in color, as, for example, being very light in color; or possibly being grassy—the color indicated by the instrument must be interpreted on the basis of a suitable weighting of the separate factors involved. The man who knows cotton is able to make such interpretations, and thus can make use of the instrument as an aid in cotton grading; the man who does not know cotton should strictly limit his interpretation to that of the average color of the sample. In the one case the instrument can become an "assistant grader"; in the other case it should remain a "colorimeter."

---

* Based on a report to the Third Annual Cotton Merchandising Clinic sponsored by the Cotton Research Committee of Texas and The University of Texas, U. S. D. A. Southern Regional Research Laboratory, New Orleans, La., May 19, 20, 1950.

† Cotton Technologist, Research and Testing Division.

Description of Nickerson-Hunter Cotton Colorimeter

The new instrument is based on a satisfactory application of the Hunter Color and Color-Difference Meter to problems of raw cotton measurement. It was found, as shown in Figure 1, that for the limited range of cotton colors a plot of Hunter's coordinates, R_d and b, provided, without conversion, a chart which is reasonably similar to that of long-established cotton measurements which are plotted in terms of Munsell value and chroma.

Since the Color-Difference Meter worked so well, specifications were written for a completely automatic instrument, which was to embody the photocell and filter combinations of the new instrument. The requirements were that the instrument maintain itself in standardization, be direct-reading on a two-dimensional scale, measure automatically, and show values graphically and simultaneously for reflectance and yellowness in a range of 40%–90% R_d and 0–20 units of $+b$.

Such an instrument was delivered for use in January, 1950. Since then it has been in almost constant operation, having already measured many thousands of cotton samples in preparation for the Universal Cotton Standards Conference which was held in Washington in May, 1950.

The operator places a sample of cotton over the sample window and steps on a foot switch. Two indicators under the chart diagram move automatically to a position of balance. Since a chart of the color of the grade standards appears on the glass panel, the operator can check a test sample against a particular position within each grade and then pass or reject it on the basis of a comparison of results with the position of the standard indicated on the instrument chart.

A top view of this new, automatic, self-standardizing instrument is shown in Figure 2; the interior of the instrument is shown in Figure 3. In Figure 2 a cotton sample is shown in position over the exposure window of the instrument, the operator has just stepped on the foot switch, and the

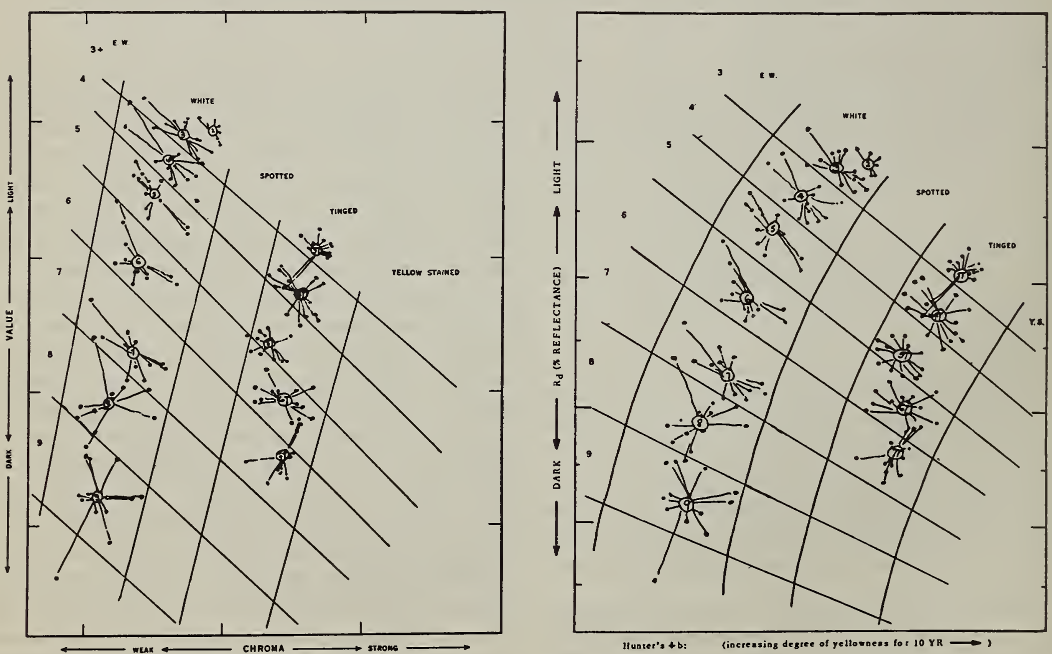


FIG. 1. *Color measurements recorded in the diagram at the left were made in 1946 by disc colorimetry and were plotted for Munsell value and chroma. The same information is shown in terms of Hunter's* R_d *and* $+b$ *color factors in the diagram to the right. For each grade the average color of each of 12 samples in each grade standards box is indicated in relation to the average for that grade.*

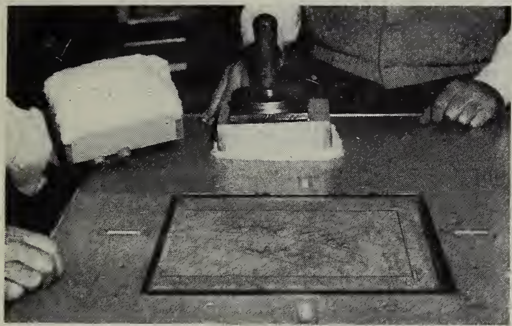


FIG. 2. *Top view of Nickerson-Hunter Cotton Colorimeter, showing a cotton sample in place over the viewing window of the instrument. The result is shown by indicators that move under the translucent center panel, on which color positions of the cotton grade standards are indicated.*

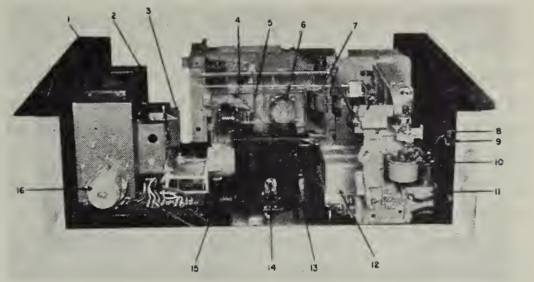


FIG. 3. *Interior view of instrument from the front. Numbers identify components.* (1—*Sample area.* 2—*Exposure head.* 3—*Lamp guard.* 4—R_d *indicator.* 5—b *indicator.* 6—R_d *balancing motor.* 7—R_d *slide wire.* 8—*Amplifier off-on switch.* 9—*Lamps-off switch.* 10—b *slide wire.* 11—b *amplifier.* 12—*Relays.* 13—CV *transformer.* 14—*Lamp for indicating scale.* 15—*Comparison balancing motor.* 16—b *balancing motor.*)

indicators have moved to a position of balance directly under the cotton scale diagram which appears on the translucent glass panel in the center of the instrument. One of the indicators moves in a vertical direction to indicate change in reflectance of the samples, R_d; the other indicator moves in a horizontal direction to indicate change in degree of yellowness of the cotton, $+b$.

The cotton grade diagram used on the instrument is based on measurements of standards that were passed at the 1946 International Grade Standards Conference and that have been in effect since August 1, 1947.

A numerical code for use in identifying the grade number and color classification of equivalent grades of American Upland cottons is given in Table I. Use of the same code by all who use the new instrument is desirable. A zero added to the code for spotted and gray cottons is suggested to identify "light spotted" (classed as 30) and "light gray" (classed as 60). The first number in a code designation is the grade number, except when the two-digit number 10 is used in the first position to indicate "Below Grade." The second number indicates the color class designations—these range from 1 for Extra White through 5 for Yellow Stained as the yellowness increases, and 6 for Grays. The code 5–1 is interpreted as Middling Extra White.

If more precise information is needed than that supplied by the use of a code referring to official grade standards, then a code consisting of measure-

TABLE I. CODE DESCRIPTION FOR GRADE OF AMERICAN UPLAND COTTON

Grade name and number			Grade color class					
			Gray (G)	Extra White (EW)	White (Wh)†	Spotted (Sp)	Tinged (T)	Yellow Stained (YS)
Name	Symbol	No.	6	1	(2)†	3	4	5
Middling Fair	MF	1			1*			
Strict Good Middling	SGM	2			2			
Good Middling	GM	3	36*	31*	3	33*	34	35*
Strict Middling	SM	4	46*	41*	4	43*	44	45*
Middling	M	5	56*	51*	5	53*	54	55*
Strict Low Middling	SLM	6	66*	61*	6	63*	64	
Low Middling	LM	7		71*	7	73*	74	
Strict Good Ordinary	SGO	8		81*	8			
Good Ordinary	GO	9		91*	9			
Below Grade	BG	10						

* Grades for which standards are descriptive.
† For the white grades, use of the color class symbol or code number is not necessary if the meaning is clear without them.

ments for R_d and $+b$ can be used, either in the form of a decimal or a common fraction. For example, for $R_d = 71$, and $+b = 10$, the code is 71.10 (or 71/10). The reflectance number should precede the yellowness number in order to keep the results in the same order as for the Munsell value/chroma specifications.

Measurement of Cottons Used in the Grade Standards

As is well known, grade of cotton depends upon color of fiber, amount and kind of foreign matter, and roughness or smoothness of ginning preparation. As is also known, the U. S. Standards for grade of American Upland cotton, known as Universal Standards, consist of 33 grades, 13 of which are represented in physical form.

Early in the color-measurement work on cotton, correlations were made of hue, value, and chroma measurements of the white cotton standards against their grade numbers. These correlations were as high as 98%, the value and chroma factors contributing about equally to the correlation, but hue not at all. On the basis of these correlations, diagrams for plotting the color of cotton since that time have been two-dimensional.

Color measurements of cotton samples are made on the basis of the composite appearance of the sample—in other words, the color measurement represents an average of the contribution made to the color of a sample by the color of fiber, the amount, color, and kind of foreign matter, and the roughness or smoothness of its ginning preparation.

Since the combination of color of lint and of foreign matter in cottons used in the grade standards fits a pattern of what is normal for each grade, it could be expected that a correlation of the amount of foreign matter against grade would be about as high as the correlation found for color measurements. In other words, for cottons already carefully selected for use in the standards, measurements of either the color or the amount of foreign matter in a sample would allow an accurate prediction of its grade in all except a very few cases.*

* Regarding foreign matter in cottons that are used for the grade standards, reference may be made to an article by the author in TEXTILE RESEARCH JOURNAL, April, 1950, pages 277–8, in which detailed measurements are given for foreign-matter content in bales used in the 1936 and 1946 standards.

Because the grade standards are put up in a specific manner out of cottons already selected by eye as a good match in color, leaf, and preparation for each position in the grade boxes, and because they are put up in cartons holding about the same amount of cotton for each sample, it has been possible to make immediate application of the new instrument to the grade-standards work. The grade diagram, based on measurements of cottons so selected and measured, applies to other cottons similarly selected and similarly prepared for measurement.

In Figure 4 the results for several typical positions in the standards boxes are shown. The large open circle in each grade block represents the average for the grade in 1946. The arrow from that circle points to the position of the color to be matched. Dots represent samples accepted as being within a reasonable tolerance for the position; crosses represent samples considered to be too far off to be acceptable. Although it is known that even for uniform bales there are differences between samples from the same bale, this is the first extensive set of data demonstrating the degree of color variation that exists between samples from such bales.

Measurement of Commercially Available Cottons

Tolerance is not the only factor that must be considered. It has been possible to make immediate use of the new instrument for such a selected series of cottons as those prepared for the grade standards because these cottons are carefully selected to represent a normal combination of color, leaf, and preparation for the grade each represents. The amount of cotton put into each carton is about the same, and the samples are measured in the cartons, a given pressure being applied at the time of measurement.

For such samples, the colorimeter becomes almost a "grader." Note the *almost.* For it should be kept in mind that this instrument is intended as an aid to the classer; it cannot replace him. And the reason that it cannot is that the instrument sees only one thing. It sees the average color of whatever appears on the face of the sample placed over its sample window. If the conditions under which a sample is tested are not the same each time, the measurements should not be compared.

Aside from the question of a standardized method of making sample measurements, there are other

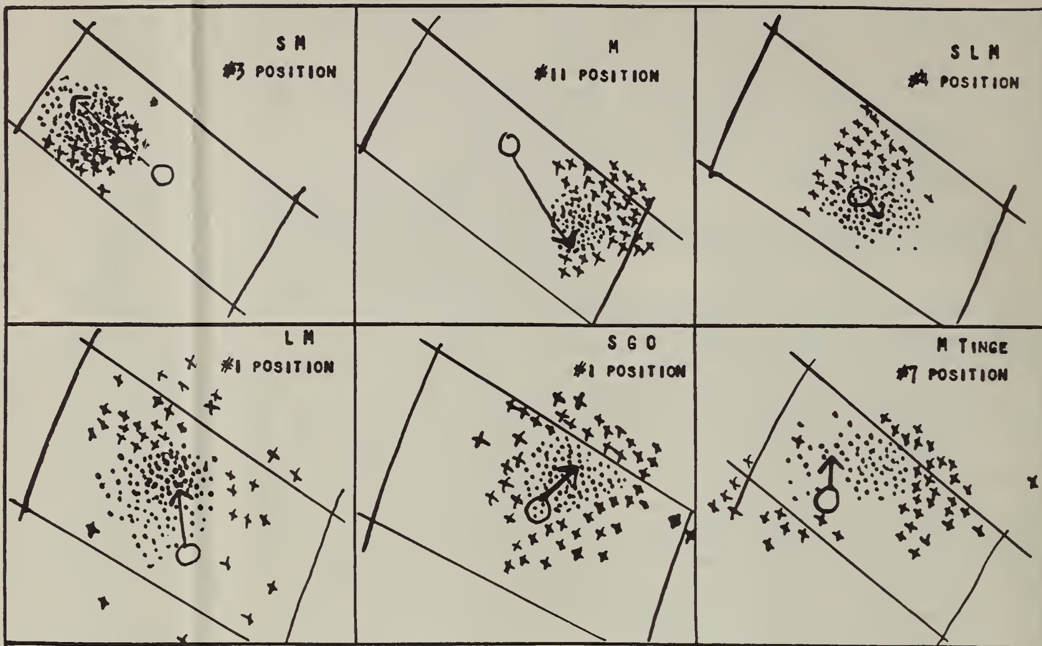


FIG. 4. *Color measurements of many samples from bales selected to be a close match for 6 typical positions in the grade standards. Note that the amount of scatter increases for the lower grades.*

matters that must be taken into consideration before one should attempt to judge the grade of cotton on the basis of color measurements. No colorimeter yet designed can tell whether the cclor it reads is the result of spots, of amount or color of foreign matter, or of general background color; all kinds of combinations can be used to produce the same average color. A classer, however, would immediately know the correct color classification. For example, a classer can see a given amount of leaf in a sample, whether it be light or dark in color. He can differentiate the general class of Gray cottons from White or Extra White cottons. Once he identifies a sample as Gray and not White, the instrument can then help him to classify it into the correct grade of Gray if a diagram for Gray standards is prepared for his use.

The same thing is true of Spotted cottons. There may be so little spot in some samples that the instrument measurement will show the same average color as for a White grade. Yet the classer would see the light spot, and by using the instrument could soon learn to place it always in the same grade. Enough tests must be made in the laboratory on cottons of all kinds in order to make up suitable diagrams. By using an automatic instrument it should be possible to maintain more constant interpretations of applicable grades for samples not represented in the grade boxes. In fact, intelligent use of this instrument should enable many more classers in the future to obtain results as accurate as those obtained by the very few who in the past have been expert in assessing color differences in cotton.

If mechanical harvesting comes into more general use, or if more effective methods of cleaning cotton at the gin are developed, the relations of color, leaf, and preparation officially set up for the present grade standards might no longer hold for large portions of the crop. Should this occur it would be necessary to study such samples in sufficient quantities, both to provide adequate data for the development of suitable diagrams for aiding the classer to determine consistent grades as they are related to the grade standards and to make it possible to recommend suitable changes for future standards.

From studies of cleaning methods, something is

now known of the color and trash relations in cleaned and uncleaned samples. A few preliminary measurements have been made on cleaned lint and on grey fabrics in order to follow-up on the relation between grades of raw stock and cleaned lint, and the color of grey cloth made from it; this study can be applied further to measurements on the bleached materials.

It should be remembered that the color range of the instrument described in this report is selected for that of cotton only. If other color ranges are required, or use of three in place of two color dimensions (as would be necessary for differentiating "pink whites" from "blue whites" or "yellow whites"), adaptations would need to be made. However, such adaptations can be made by the manufacturers, since the principles upon which the instrument is designed are completely adaptable to use for other limited ranges of colors, in either two or three dimensions.

Literature Sources

This paper summarizes information that appears in the following papers, each of which carries full literature citations:

1. Nickerson, D., Hunter, R. S., and Powell, M. G., New Automatic Colorimeter for Cotton, *J. Optical Soc. Am.* **40**, 446–9 (1950).
2. Nickerson, D., Color Measurements of Cotton, Preliminary Report on Application of New Automatic Cotton Colorimeter, U. S. Dept. Agr., Apr. 1950, 18 pp., illustrated. (Processed.)

(*Manuscript received May 31, 1950.*)

UNITED STATES DEPARTMENT OF AGRICULTURE
Production and Marketing Administration
Cotton Branch

COLOR MEASUREMENTS OF COTTON

Second Report on
Application of Nickerson-Hunter Cotton Colorimeter,
Including a discussion of recent work on standards for grade

By Dorothy Nickerson, Cotton Technologist, Research and Testing Division

Washington, D. C.
March 1953

ACKNOWLEDGMENTS

The work reported in this publication is a part of the research program under the direction of John W. Wright, Chief, Research and Testing Division, Cotton Branch of the Production and Marketing Administration U. S. Department of Agriculture. The studies relating to the preparation of grade standards were made in cooperation with Rodney Whitaker, Chief, and H. C. Slade, in charge of standardization, in the Marketing Services Division of the Cotton Branch.

CONTENTS

SUMMARY

Grade of cotton consists of three factors--color, foreign matter, and ginning preparation--and the average color of an adequate sample, measured on a colorimeter, represents the color of the combination of these three factors. Measurement of separate factors, and of the three factors in combination, as an aid in grade standardization, has been used in the cotton standardization work of the U. S. Department of Agriculture for at least 25 years. In 1950 the successful development of an automatic colorimeter for cotton made it feasible to extend the color work so that anyone with sufficient interest could understand and verify the various aspects and problems of grade standardization work.

Since grade is one measure of cotton quality and a primary basis for price quotations, and since grade is arrived at--and arbitrated against--by government standards, the entire cotton industry should have a general understanding of what the grades are, how the standards for grade are made, and the problems involved in preparing standards in physical form.

In 1950 a preliminary report announced a newly developed automatic colorimeter and described some of its applications and limitations. The present report goes into more detail regarding factors considered in preparing grade standards, color change that may be expected when cotton is stored for long and short periods of time, and the degree of color variation that exists in bales selected to be as uniform as possible.

This report includes information presented at preliminary and final conferences held in 1951 and 1952 regarding preparation of the standards for grade that were adopted in August 1952, effective August 1953. The history of recent standards is given, including the fact that no changes were intended in the 1946 and 1950 standards, but that changes were intended in the 1952 standards. Results of recent surveys are shown in detail, particularly of the 1950 crop, and the need and desirability are discussed for providing a natural standard for all grades developed in physical form.

Details are included regarding changes in the color diagram for the new standards, the measurements of trash content of bales used in the 1952 standards, and the color measurements on these bales after trash removal.

The use of the colorimeter in measuring cottons other than those used for standards is discussed at some length, for White, Spotted, Tinged, Yellow Stained, and Gray cottons; for combinations of grade factors that are not within the standard grades; for seed cotton, for cleaned lint; and for measurements of grey yarns and fabrics.

The new colorimeter is described, references covering principles of color measurement are provided, and a description is given of two tests in the Cotton Testing Service that aid in calibration of the colorimeter.

COLOR MEASUREMENTS OF COTTON

Second Report on
Application of Nickerson-Hunter Cotton Colorimeter,
Including a Discussion of Recent Work on Standards for Grade

By Dorothy Nickerson, cotton technologist

INTRODUCTION

The color of raw cotton has been measured in the U. S. Department of Agriculture as part of the work on standards for grade for a great many years. In early years a visual disk colorimeter was used, but in recent years a new automatic, photoelectric instrument has been developed. In April 1950 a preliminary report (5) 1/ was published on the application of this instrument, then new, the Nickerson-Hunter Cotton Colorimeter (9). One section of that report discussed the subject of measurement of cottons for use in grade standards, and another section discussed the measurement of cottons other than those used in grade standards.

Since 1950 a great deal of work has been done with this colorimeter. Instead of the single instrument available in 1950, when the first report was prepared, more than 40 were in use by January of 1953. Of these, 5 were in use in Government cotton classing rooms. The others were being used in classing rooms of mills, shippers, and arbitration boards in the United States and abroad. In view of such use, a second report on the application of this automatic colorimeter appears to be timely so that those who use the instrument, or those interested in the results of this or any other type of colorimetric measurement of cotton, may have before them information based on the experience of the Cotton Branch in its color work on cotton standards and classification.

DESCRIPTION OF THE COLORIMETER

The colorimeter referred to in this report is one developed by the color laboratory of the Cotton Branch in cooperation with R.S. Hunter, then chief optical engineer of the Henry A. Gardner Laboratory which manufactures the colorimeter. The instrument is based on the principles of tristimulus colorimetry (3), but its range of measurement is limited to the colors of raw cotton. The colorimeter averages the color of a sample about 4x4 inches in size. Results are indicated directly on the instrument in terms of two scales, one measuring reflectance and the other the degree of yellowness. Superimposed on these scales is a diagram based on average measurements of the color of the cotton used in the standards for grade.

The instrument is electronic, it is self-standardizing, and it is automatically indicating. A sample is put over the window of the instrument, a hand-or foot-switch is pressed and the indicators then move automatically to a position of balance. This position may be recorded in terms of the color scales of the instrument or in terms of the color of the standard which it most closely approximates for grade.

1/ Underscored numbers in parentheses refer to Literature Cited, p.37.

For the automatic standardization and automatic indication features, Brown Instrument components are incorporated into the instrument, Brown 60-cycle balancing motors for the self standardization feature, and Brown Amplifiers with converters, balancing motors, and moving scale indicators for the automatic indication feature. 2/

A number of improvements have been made in recent models, but the principles used in their construction are the same as those reported in 1950 (9).

Modern colorimetry is a highly technical and specialized field, and the development of visual and instrumental scales for expressing color and color difference measurements lies in that field. After development, many color measuring instruments require considerable skill in operation and the services of a well qualified physicist or other technical person to operate and keep them in calibration. Such instruments usually require operation in a laboratory, by technical laboratory workers. This cotton colorimeter, on the other hand, is designed to be used in the classing room by the cotton classer. The electronic design is not simple, yet--like a television set--the instrument may be tuned for efficient use in a fairly simple manner. Calibrating the cotton colorimeter is like tuning a television set for which dials are provided for controlling several variations. If something really goes wrong, something for which no provision has been made for adjustment, the services of an instrument specialist may be required to locate the trouble and make the adjustment. Yet in most cases, as with a television set, it can be expected that this cotton colorimeter will give satisfactory service in the hands of an intelligent operator. It is, however, important that the colorimeter operator be a good judge of cotton, since for each cotton sample measured it is the color information provided by the instrument plus its interpretation by the classer (as regards the color classification, the amount of trash, and sample preparation) that makes this colorimeter a useful classing aid. The instrument itself is a colorimeter, but in the hands of a competent classer it can become a very useful aid in assigning consistent and accurate grades.

Details regarding calibration tests are discussed on page 36.

PRINCIPLES OF COLOR MEASUREMENT

To use the colorimeter it is not necessary to know the principles upon which the color measurements are made and specified. However, those persons who may wish to have a general background of information on color measurement are referred to two previous reports (5) (6), each of which includes a reference list. One report (5) contains a brief summary of pertinent information in its Appendix, pages 14-18. The other report (6) includes a discussion of general color grading problems, of various available methods, of color tolerance specifications, of artificial lighting for grading work, 3/ and color vision testing.

2/ Most areas in the United States are covered by Brown representatives familiar with these parts. Refer to Minneapolis-Honeywell Instrumentation Data Sheet No. 10.10-3 (1951).

3/ See 1952 Cotton Classing by Artificial Light, by D. Nickerson, Illum. Engin. 47, 135-142 (March 1952).

The best, in fact the only, general reference work covering the greater part of this field of applied colorimetry is a recent, and authoritative, book by Judd (4) of the National Bureau of Standards. He discusses basic facts, tools and techniques, and gloss, opacity, and colorant problems. Figure 43 of his book shows curves of the Hunter tristimulus filters, two of which are used in the cotton colorimeter. In a section on Uniform Color Scales, the development of Hunter's scales is discussed, from formulas used in 1941 (formula numbered 27) to those used for the reflectance (R_d) and yellowness (b) scales of the cotton instrument (formula numbered 32a). Since the colorimetric portion of the cotton colorimeter is based on the Hunter Color Difference Meter, these discussions in Judd's book are pertinent to any real study of the principles on which the color portion of the cotton colorimeter operates.

FACTORS TO CONSIDER IN PREPARING STANDARDS FOR GRADE

There are two factors regarding color, often overlooked or minimized, that should be taken into consideration in preparing standards for grade of cotton. One factor is that color of cotton changes with time, particularly in the high grades. The other factor is that within each commercial bale of cotton, no matter how uniform it may appear to be, considerable variation in color can be expected.

Color Change with Time

Figures 1 to 6 indicate color changes in cotton due to storage. Figure 1 is taken from a report on color change in storage (7). The open circles represent cotton (Missdel 4, grown at Stoneville, Miss., in 1931) picked from a single field of cotton for 14 successive weeks and measured for color within a week or two after picking. The closed circles represent measurements of the same cottons 2 years later, and the triangles represent the same samples measured 17 years after picking. The samples picked in the first 6 weeks--in fact all samples that originally were as good as Middling or Strict Middling in color--had yellowed considerably during the first 2 years while stored in Washington laboratory space. Seventeen years later, practically all cotton that originally was the color of Low Middling or above had yellowed, in fact the Strict Middling Whites had yellowed enough in that time to become Yellow Tinged in grade.

This constant yellowing of cottons from the time they are picked in one season to the time they are used in the standards poses a real problem in cotton grade standardization. By the time that new standards are adopted the cotton in them is at least one crop year old, often more.

In certain years, or in certain storage places, cottons may yellow faster than at other times or places. For example, in Gulf port cities where both temperature and humidity may be high during the storage period, the yellow color will develop faster than it does in storage places in drier locations, whether high or low in temperature.

Figures 3 to 5 illustrate the kind of change that occurred when samples were stored for short periods of time under what might be considered normal storage conditions. These figures illustrate cottons from the 1951

crop that were bought and used during the winter and spring of 1952 for making the new standards for grade. The cottons were bought to fit the color pattern of the set of boxes shown to representatives of the cotton industry in 1951, which had been made from samples from the survey of the 1950 cotton crop. Figure 2 shows the color pattern used as the goal, each grade to be represented by six bales. Figure 3 shows the pattern of cottons actually obtained, as they were measured during the winter and spring of 1952 while 100 or more sets of boxes were being put up. From these boxes a representative set was selected to be shown to domestic and foreign representatives of the cotton industry in June and July of 1952. By the fall of 1952, measurements of other samples from the same bales, but which had been stored in the warehouse, showed the change illustrated in figure 4. It was a hot summer in Washington, hot enough and evidently with high enough humidity to cause excess yellowing in the Strict Middling and Middling White grades, and in a few of the bales in the low grade Tinges stored in the warehouse, even though the warehouse was in the same building in which the classing room was located.

The series of diagrams in figure 5 represent measurements of one set of standards taken from the series illustrated in figure 3. This set--No. 3--was measured in June (figure 5A), and again in August (figure 5B) after the new standards for grade were promulgated; in the meantime the sets had been held on the fifth floor in the classing room which is air conditioned during working hours. A comparison of the information provided by figures 2 to 5, shows that the place of storage, even within the same building, can make a difference in the color of the cotton. Set No. 3 was made from the cotton represented in figure 3, yet Set No. 3 when measured several months later had not changed nearly so much as had the cottons held in the warehouse.

Color may also bleach out and become whiter, but that should not create a problem except when samples are exposed to too much light. It should not affect cotton within the bale, although it could affect cotton on the bale exterior if exposed to direct sunlight for many hours. It could take place, perhaps, in boxes of standards if they remain open in the light too long. Figure 6 illustrates what happened to two boxes of Strict Middling from the 1952 standards.

The history of these two boxes of Strict Middling was as follows: When it was found necessary to make up 12 instead of 6 sample boxes for the standards, the extra cartons that already had been put up from each bale that was used were brought up to the classing room from a lower floor in the warehouse. The work of adding to the stock of standards boxes began early in September 1952, in making first preparations for a conference in 1953 to review duplicate boxes of the standards adopted in 1952. Immediately it was found that samples stored in the warehouse on the 2nd floor had yellowed more than had samples from the same bales that were kept in the classing room on the 5th floor.

The summer of 1952 was unusually hot in Washington, and the warehouse had no relief from the heat, whereas the classing room on the 5th floor was air conditioned during working hours. That was the only storage difference that could be accounted for since the entire bale of cotton had been examined and put up at one time into small cartons to fit the standards boxes. The preparation of samples from the bale was done in field offices of the Cotton

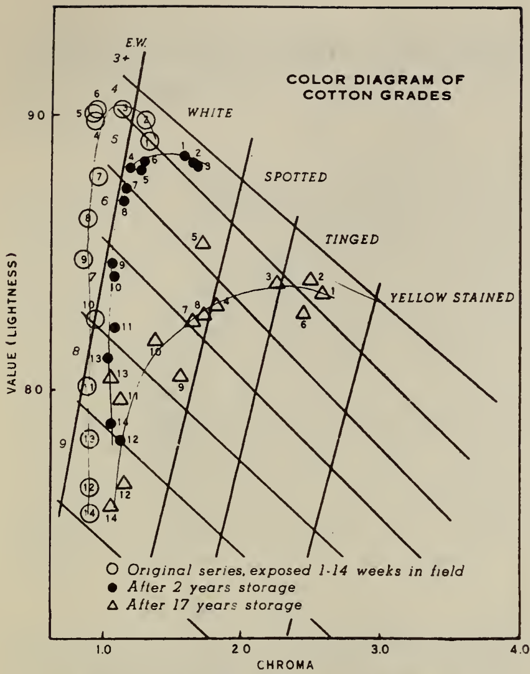


Figure 1.--Effect of storage on a series of 14 cotton samples. Color shift is indicated for 2 and 17 years.

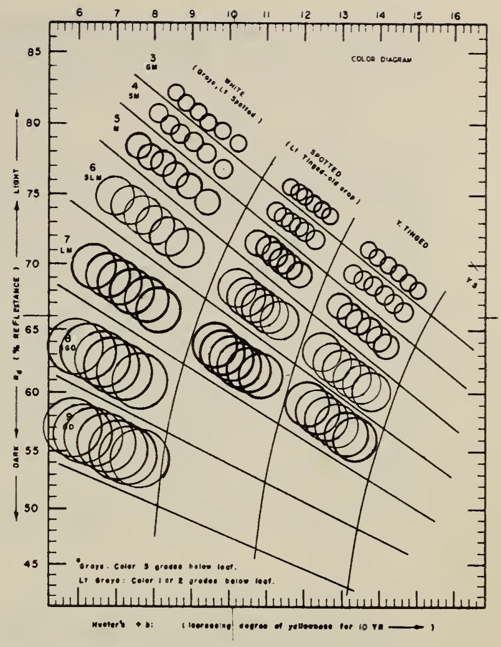


Figure 2.--Color range within grade standards: Regular pattern used as goal.

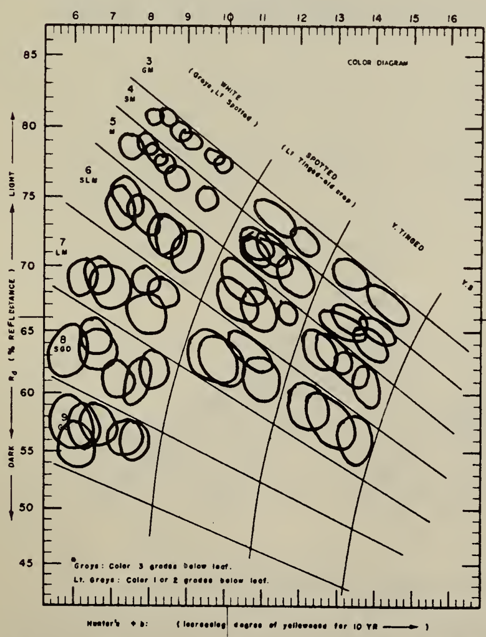


Figure 3.--Color range within grade standards: As obtained and measured during preparation of 1952 standards.

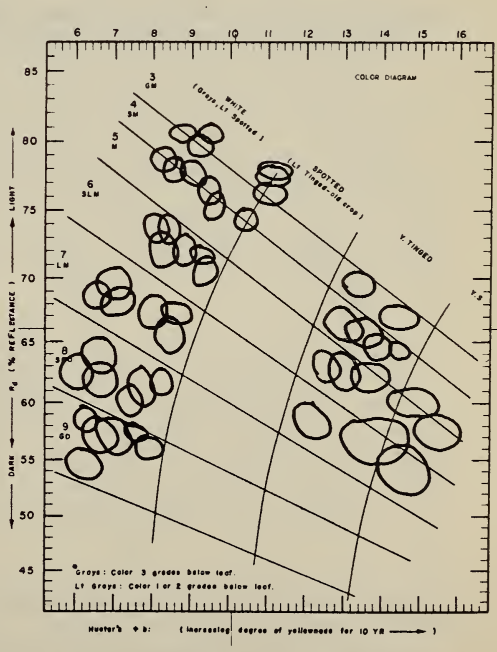


Figure 4.--Color range within grade standards: Range for bales in figure 3, but after summer storage.

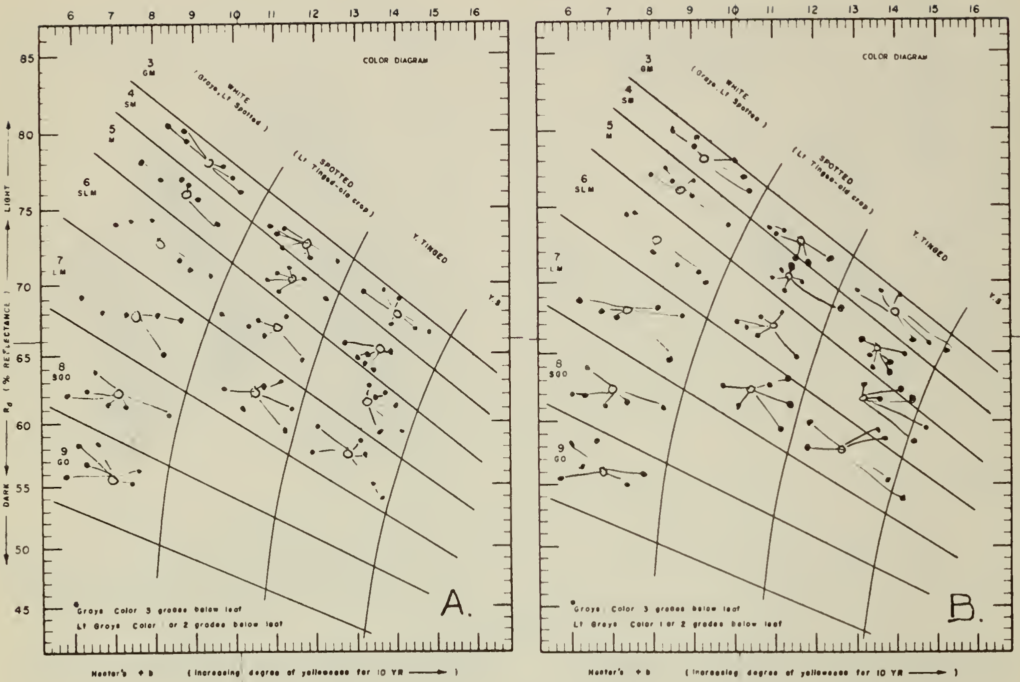


Figure 5.--Color of one set of actual samples from 1952 standards: A. Measured June 1952 before first meeting; B. Measured late August after promulgation of standards.

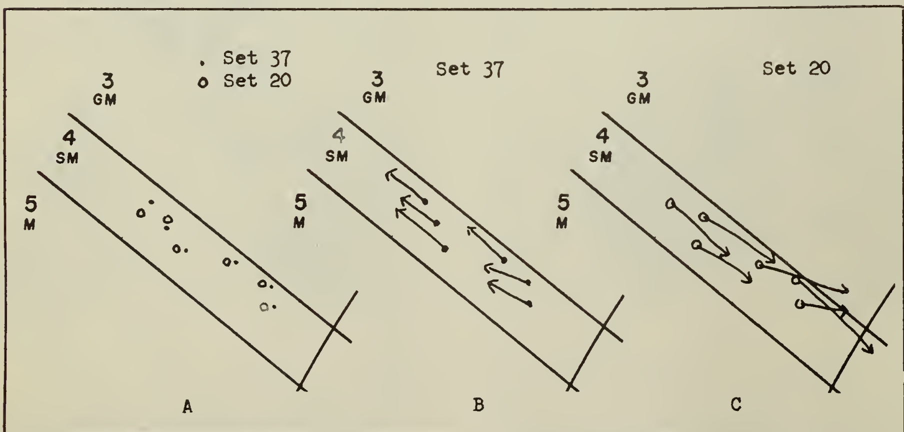


Figure 6.--Color of samples in a pair of Strict Middling boxes--from Sets 37 and 20--before and after exposure of one box to sun and sky, and the other box to heat of basement panel room. Bleaching action whitened samples in Set 37, yellowed those in Set 20. Diagram is similar to previous figures, but limited to portion centering about Strict Middling.

Branch in Atlanta, Memphis, Houston, and El Paso.[4/] For each bale the samples were prepared at one time, the samples having been examined for uniformity of leaf and preparation by classers in the local offices at the time they were put up.

The finding of such a considerable color difference in cottons already selected and purchased for use in the standards naturally was disconcerting. Since it was known that cottons would yellow, it was decided to make a test to see how much sunlight might bleach them, and thus return them to a whiter color again. Two sets--No. 37 and No. 20--of Strict Middling standards made from bales used in preparing the 1952 standards, illustrated in figure 3, were selected for test. No. 37 was exposed on the roof to about 40 hours of sunny, or slightly hazy sky and No. 20 was placed in the electrical panel-board room in the basement, the nearest thing in the building to a boiler room. The results are illustrated in figure 6. Diagram A shows how closely the samples in the two boxes were color matched at the start of this test. After about 40 hours of intermittent exposure on the roof to the sun and sky the color of samples in Set No. 37 had bleached, and the color of samples in Set No. 20 stored in the basement room had yellowed. Diagrams B and C of figure 6 illustrate the extent of these changes.

Since this kind of change occurs, one might ask why conditions of storage cannot be standardized so that the color of standards during and after preparation may be kept as constant as possible. The answer is that it does not seem practical to go to the great expense necessary to apply continuous air conditioning to all storage and work space used in connection with preparation and storage of grade standards, particularly since this would help to keep them constant only <u>before</u> purchase, the standards are used under all kinds of conditions after purchase. And if a single set--perhaps the original--were put into a deep freeze for storage, then the standards regularly made from the same bales would not look the same as the refrigerated original. As color measuring equipment has become available for making prompt measurements of large numbers of cotton samples, it has been possible to record changes that for years have been recognized as occurring, yet have been discounted heavily when the time came to "match" new boxes of standards to those put up at earlier conferences. All that is new at the present time is that we know what the situation is and everyone can follow the degree of change.

One obvious answer, and at a minimum of cost, would be to make the original selection of bales to fit a regular pattern of color based on the average colors of many crops, then let the standards boxes represent leaf and preparation, but let them represent color only insofar as the color has not departed from the color of the bale as and when it was established originally in the standards. Each time that purchases would be made for complete grade boxes the color would be brought back to the color of the original pattern.

4/ Under the general direction of Hughes Butterworth, who purchased the cotton, this work was in charge of Ben V. Person, Atlanta; Sidney Holman, Memphis; Herbert J. Matejowsky, Houston; and Stanley Rademaker, El Paso.

There are some who may honestly believe that use of color measurements in preparing cotton standards has been the cause of changes made in the standards. On the contrary, the only way that standards in physical form can be kept at a constant level, even at the time of original preparation, is to find a way to measure the factors that are included in that standard.

Bales for standards are selected by classification, first and always. No bale is used in Middling that has not first been called Middling by trade classers, then by Government classers. No bale is intended for use in the standards unless it has passed visual inspection by the classer for all factors involved--color, leaf, and preparation. After bales are visually selected by the classer, laboratory instruments make it possible to select bales that may be more regularly graduated in these various factors than they would be if based on visual judgment alone. In fact, constant visual judgments for uniformity within a bale are so difficult to make that only a very few classers become expert at this specialized phase of classing work--most classers who have colorimeters available find it easier to let the colorimeter make the judgment for uniformity. When classers first do this, they often expect too much of the instrument, for it is easy to forget that the instrument sees only one thing--the average color of whatever surface is placed on the colorimeter window. The human classer sees many things about cotton at one time, and he integrates several separate factors into a single designation of grade. The colorimeter sees many things too, but all at once, as an average color, with no power to analyze and break down this single average into its several factors. The human classer has a brain; the instrument does not have a brain.

As it becomes possible to measure other grade factors with some degree of assurance, it is conceivable that a higher degree of correlation may be found between measurements of grade factors and classers' grade. But at present if the color instrument shows the average color to be in the range of a single grade, the classer must use his judgment. For example, as stated later in this report, if the color measurement falls in the block representing Low Middling color then the classer must judge for himself whether the sample is White, with Low Middling leaf and preparation (in which case the sample is Low Middling White), or whether the color is Light Spotted, and the leaf Low Middling (in which case the interpretation would be Low Middling Light Spotted), or whether the leaf may be Middling and the color Low Middling (in which case the interpretation would be Middling Light Gray).

On the color diagrams based on the new standards, these possibilities are indicated. They are not indicated on the diagram for the earlier standards because at the time the first diagram was prepared it was not foreseen that such information would be so important to a correct interpretation of grade by users of the colorimeter.

Although information regarding changes in storage is presented, and attention is called to the difficulties of keeping the color of physical standards constant, it is not to be expected, merely because standards are measured, that they can at all times be kept constant. A practical compromise must be made and such changes as are described must be taken into consideration in developing standards for grade in physical form.

Color Variation Within Bales

Color variation within bales is another factor that must be taken into consideration in the preparation of cotton grade standards. The color variation in bales, selected at random from color measurement data on bales used in preparing the 1952-53 grade standards, is illustrated in figure 7. It should be remembered that figure 7 illustrates the minimum of variation to be expected since bales used in the standards are selected to be as uniform as possible. If bales are to be selected that are capable of supplying a large number of samples, then bales that average close to any of the limit lines on the diagram must be avoided. Samples that measure on the line on the chart may be called one grade as

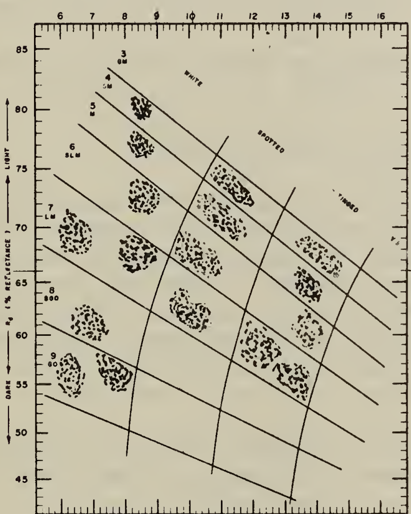


Figure 7.--Variation within uniform bales. Each group of dots represents samples from one bale.

often as another, but for use in standards it is better to have bales clearly within a single grade for all grade factors, with no overlapping. Certainly the bales should be within their grade block on the diagram when first selected for use, even though it is known that thereafter the cotton may yellow enough to approach or even attain the color of another grade. Since leaf and preparation factors do not change as the color changes, a bale may remain in the original grade when it is clearly in that grade for leaf and preparation, and a line bale for color. But such a bale should be avoided if it measures on the line for color at the time when original bale selections are being made. Bales of this kind soon enough find their way into the standards--time will take care of that!

With at least the amount of variation illustrated in figure 7 to be expected in all bales of cotton, it becomes clear that tolerances that wide must be allowed between copies of the standards. It could become prohibitive in cost to attempt to keep grade boxes any closer together than can be done by use of samples carefully assembled from uniform bales. The colorimeter is the thing to use when finer discriminations are needed.

USE OF COLORIMETER IN PREPARATION OF COTTON GRADE STANDARDS

The application of color measurements to the preparation of cotton grade standards was briefly discussed in the 1950 preliminary report (5) That report made during the first months of operation of the new automatic cotton colorimeter, referred to its use in connection with preparing for the International Grade Standards Conference held in Washington May 1-5, 1950. Although the discussion in that report is as pertinent today as it was then, there have been new developments both in the colorimeter and in the grade standards since 1950.

One important improvement [5/] in the colorimeter since the preliminary report was a change in the size of the cotton sample that is measured. On the first instrument the sample measured was about 2-1/2 by 3-1/2 inches; on all later instruments the window size has been increased to about 3-3/4 by 4 inches.

As for standards, there have been changes in these, too. New standards for grade were promulgated (10 on August 15, 1952, effective August 15, 1953.

History and Adoption of 1952 Standards

Information concerning the new standards for grade has been widely circulated throughout the cotton industry. This was done in the summer and fall of 1951 through a series of meetings at which preliminary forms of the proposed new standards for grade were shown to representatives of the industry and fully discussed. Then in 1952 final forms of new standards, based on the results of the 1951 meetings, were proposed. Never before in the history of cotton standards was there a greater effort to get the understanding and assistance of representatives of the cotton industry in preparing a new set of standards.

Information regarding color and trash of special and regular surveys was assembled and presented in a series of charts, and a proposed tentative set of standards, made from samples of the 1950 survey, was demonstrated The 1951 meetings with representatives of the cotton industry began in Washington and were extended to eight local cotton centers in the United States--from Boston, Mass., to Bakersfield, Calif.,--with a final meeting held at Le Havre, France.

On the basis of suggestions and reactions to the set of samples proposed in 1951, cotton was purchased and actual sets of standards were prepared beginning in the late fall of 1951. It took the time of many persons all winter and spring to assemble the bales of cotton and work up the new standards. About 140 sets of 6-sample boxes were prepared. These sets were intended to duplicate closely, except for such minor changes as had been suggested, the range of cottons approved in the preliminary set shown in 1951. On June 19, 1952, a set taken at random from those prepared was shown to representatives of the cotton industry at a public meeting held in Washington. In July, two sets of 6-sample boxes

---

5/ There have been many optical, electrical, and mechanical improvements in the colorimeter since the first instrument was developed in 1950, but none has made any essential difference in the color results.

were put into a single 12-sample set and this, together with the 6-sample set shown in Washington, was taken to Le Havre, France, for inspection and action by delegates representing signatories to the Universal Standards Agreements. The 12-sample set, made from the same bales and judged equal in all respects to the cotton in the 6-sample set, became the new Original Standard. It was sealed up at Le Havre and placed in a vault in Washington on its return.

Insofar as possible, the several cotton-growing areas are represented in the boxes of standards in the following positions:

Area	Position in small box	Position in large box
South Central------	Nos. 1-2	Nos. 1-4
Southeastern-------	No. 3	Nos. 5-6
Western------------	No. 4	Nos. 7-8
Southwestern-------	Nos. 5-6	Nos. 9-12

The proposed new standards were approved by virtually all the cooperative associations and by shipper and merchant groups as well as most cotton exchanges in this country, but with the very definite request that a 12- and not a 6-sample box be promulgated. Domestic mill representatives requested that the color and preparation of the proposed standards be raised, they opposed changing the Spotted grades from descriptive to physical standards, but they approved a 6-sample box. Delegates at Le Havre accepted the White and Tinged standards, but opposed adopting Spotted standards in the form presented; they preferred a 12-sample box.

Since any real change in the cotton already purchased and worked up for the proposed standards would have delayed a change in standards for another year, and since a very considerable majority of the representatives of the cotton industry approved the White and Tinged standards, they were promulgated August 15, 1952, to become effective August 15, 1953. Spotted standards in physical form were not included, nor was Good Middling for which cotton was not available for a new box. It was agreed that every attempt would be made to provide boxes embodying the changes requested for the Spotted and Good Middling White grades in time for presentation at a 1953 conference which would be called to approve copies of the standards promulgated.

During all the many conferences that led to the adoption of new standards in 1952 full information was available and presented on every phase of the preparatory work, particularly on the color measurement work. This was done by oral presentation and by means of large charts, for the benefit of all who attended the public meetings, or who came to Washington to see the material. Since this information, particularly the charts involving the color work, has not previously been published, it is included in this report. Thus the information in this publication will serve two purposes: (1) It will constitute a record of the general way in which the standards were prepared; and (2) it will indicate the particular way in which the cotton colorimeter can be used in preparing standards.

No Change in Standards Intended in 1946 and 1950; Change Deliberate in 1952

In 1946, directly after World War II, a conference was held to approve copies of standards for grade then in effect. In the 7 years following the 1939 conference the color of the grade standards showed such a very obvious change that delegates were requested to come to the 1946 conference prepared to adopt new standards. There was no intention on the part of the U. S. Department of Agriculture of making any general change in the standards, but it was realized that if the 1946 boxes were put up to appear as close as possible to the 1939 set of standards "as and when established" in 1939, the 1946 copies would look so little in color like the 1939 original set as it had changed by 1946, that objection would surely be raised by some persons that the 1939 set was not being matched. Therefore, even though no change was contemplated, delegates were asked to consider the 1946 set as new standards and thus avoid this dilemma. The dilemma occurred, however, becaus the domestic mill representatives took the position that the grades had been lowered, and they left the meeting before final consideration by the conference at which the standards were adopted.

In 1950 a conference was held which was considered successful by all who took part. 6/ The purpose of the conference was outlined by the Chairman 7/ as follows:

> "It is the sole purpose at this conference to examine and approve copies of the original Universal Standards as and when they are established. The tendency of the samples representing the original Universal Standards to change in physical appearance is to be taken into account by the experts in examining and approving the copies of the standards at this meeeing and they must not depart from their original Universal Standards as and when they were established."

Although the 1950 sets of standards were approved by representatives of all groups participating in the conference, questions were raised concerning revisions that would include physical standards for Spotted and Gray cottons. In connection with any such revision of standards the Chairman stated that:

> "the Department this year (1950) will make a rather careful survey of the crop with particular emphasis on standardization. If this survey indicates that the standards do not fit the cotton in the crop, I think that we should prepare boxes that in our judgment do fit the crop and present them to various interested persons within the next two years."

6/ 1950 Universal Cotton Standards Conference of 1950. Cotton Branch, Prod. Mktg. Admin., U. S. Dept. Agr. 28 pp., mimeographed.

7/ Rodney Whitaker, Cotton Branch, Prod. Mktg. Admin, U. S. Dept. Agr.

Survey of 1950 crop

Because it was aimed at a specific goal, the survey of the 1950 crop differed somewhat from the statistical method used to obtain most of the previous periodic surveys of the grade and color of the United States cotton crops since 1931. In 1950 each of the 26 classing offices of the Cotton Branch was requested to prepare a representative set of samples for all grades classed in the respective offices during the classing season. At the end of the season the chief of the standardization section 8/ visited each of the 26 classing offices and went over each set with classers in the originating office, after which the 26 sets of samples were sent to Washington for measurement and for assembly into a single representative set of samples.

As was true of the cottons used in the 1950 standards, color measurements were made on the cotton colorimeter for every sample submitted. The resulting data were studied on the type of color diagram shown in figure 8. This diagram was drawn on the basis of the 1946 and 1950 standards. Averages for the 12 samples used in each of the 1950 grade boxes are shown on this diagram.

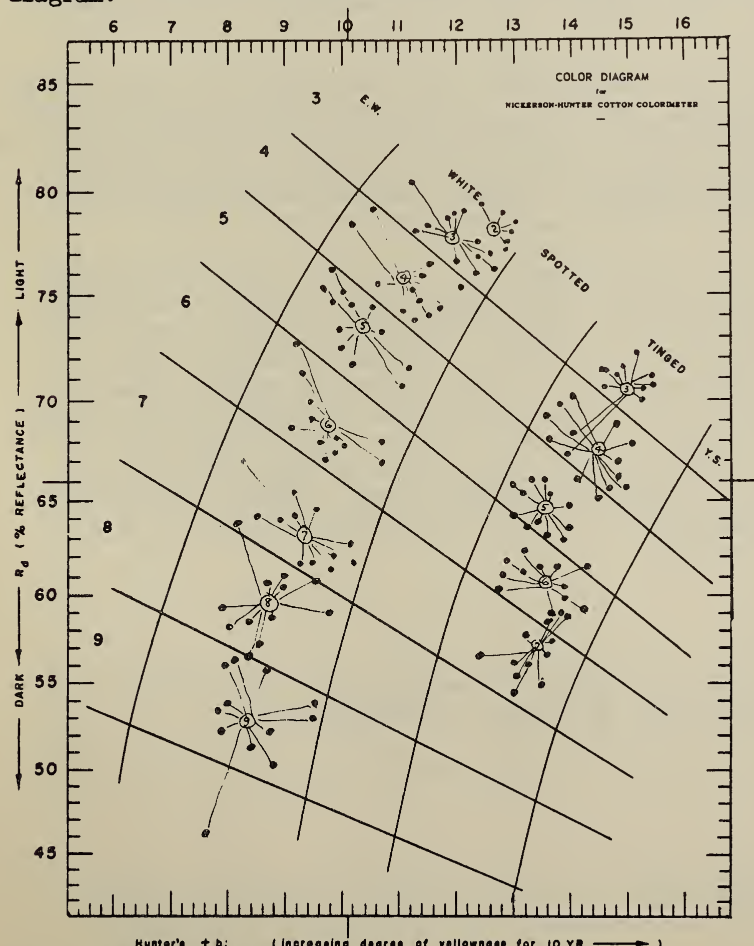


Figure 8.--Heavy dots represent measurements for 12 samples in each of the 1950 grade standards boxes.

Results of Surveys Show Old Standards Too Yellow

Results of the 1950 survey are illustrated in figures 9 and 10. 9/ In both figures the background diagrams were based on the 1946 standards.

On figure 9 each dot represents a sample of cotton. On the four diagrams all cottons received in the 1950 survey that were called White, Light Spotted, Spotted, or Tinged are plotted. From a study of these diagrams it becomes immediately clear that the standards passed at the 1950 conference do not fit the color of this crop. And as compared to previous surveys, this crop was no different in general color than others of recent years.

To indicate more clearly just how the separate grades were arranged, representative sets of White cottons submitted by 4 of the 26 classing offices are shown in detail in figure 10. Although the color of the Texas-Oklahoma crop may average yellower than the average of Mississippi-Arkansas, or of Carolina cottons, or those of the far West, yet--as the color results for classing offices representing all four of these areas show in figure 10--all the cottons were either on the white side, or they were whiter (grayer in the low grades) than the cottons in the old standards, as passed at the 1950 conference.

Practically all the higher grades, with the exception of some of the samples from the Southwest, were white enough so that they could be called Extra White on the 1946 or 1950 standards. The 1950 survey provided information that pointed unmistakably to the need for a change in the standards, and it also provided representative samples from all cotton growing areas of the United States from which to make up a preliminary new set.

Classing and color results for 1950 and for 1949 (the first survey measured on the new colorimeter), were compared for averages of all White and Tinged grades classed in four areas. Although differences were found, the general picture of results for 1949 was similar to that for 1950. From these and other supporting data it was determined by the standardization and classification staff of the Cotton Branch that the most important change necessary to be made was one of color, that is, a change that would shift the standards to whiter (or grayer) cottons so that the standards would represent cottons occurring in current crops. Neither by classification nor by color measurement did it seem necessary to change the general level of the grade standards.

9/ Detailed data from surveys of recent cotton crops will be discussed in a separate report in process of preparation.

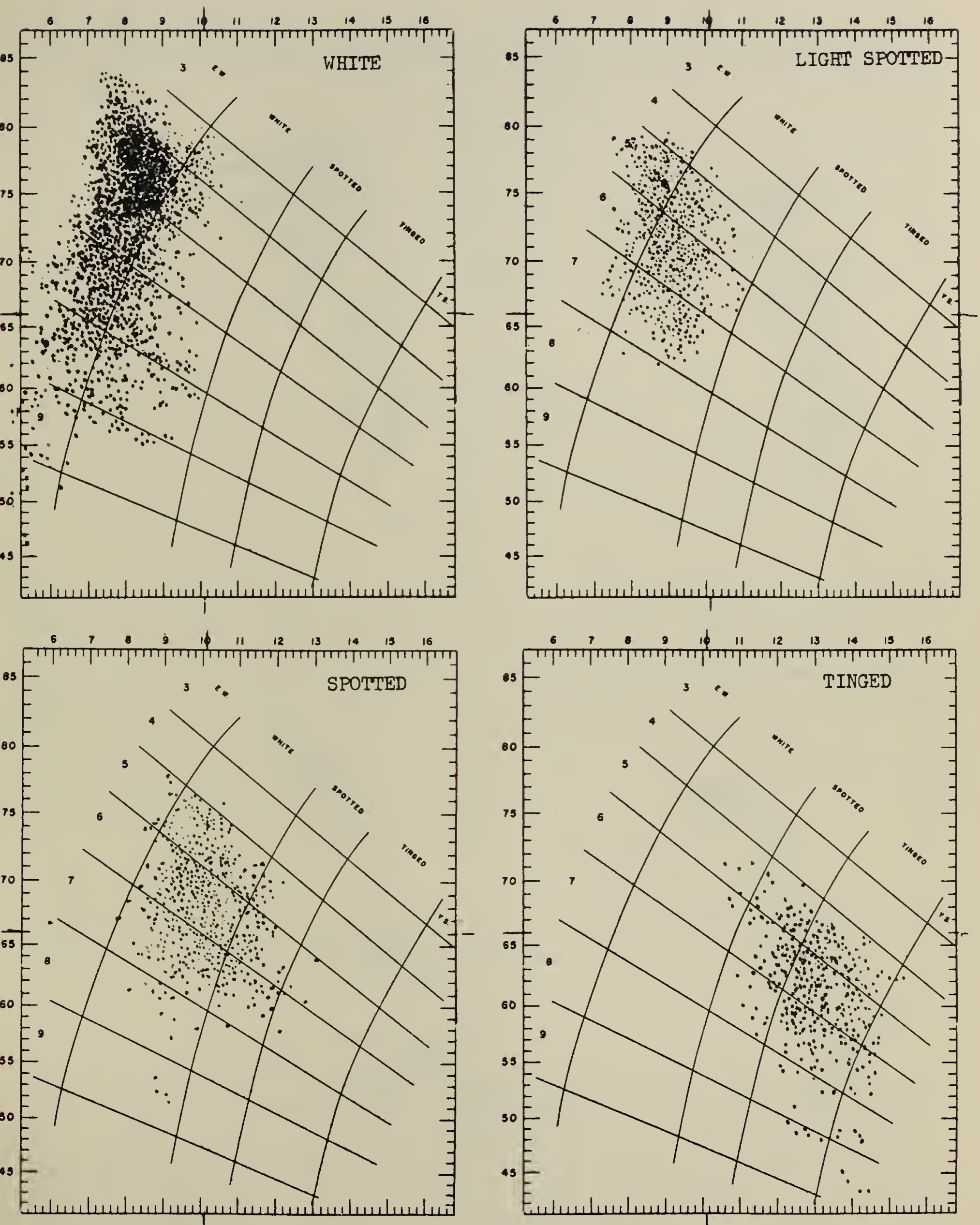


Figure 9.--White, Light Spotted, Spotted, and Tinged cottons in 1950 grade survey. Each dot represents a sample of cotton; all samples submitted are included. The grade diagram is based on the 1946 standards measured in terms of Hunter's R_d (vertical scale) and +b (horizontal scale).

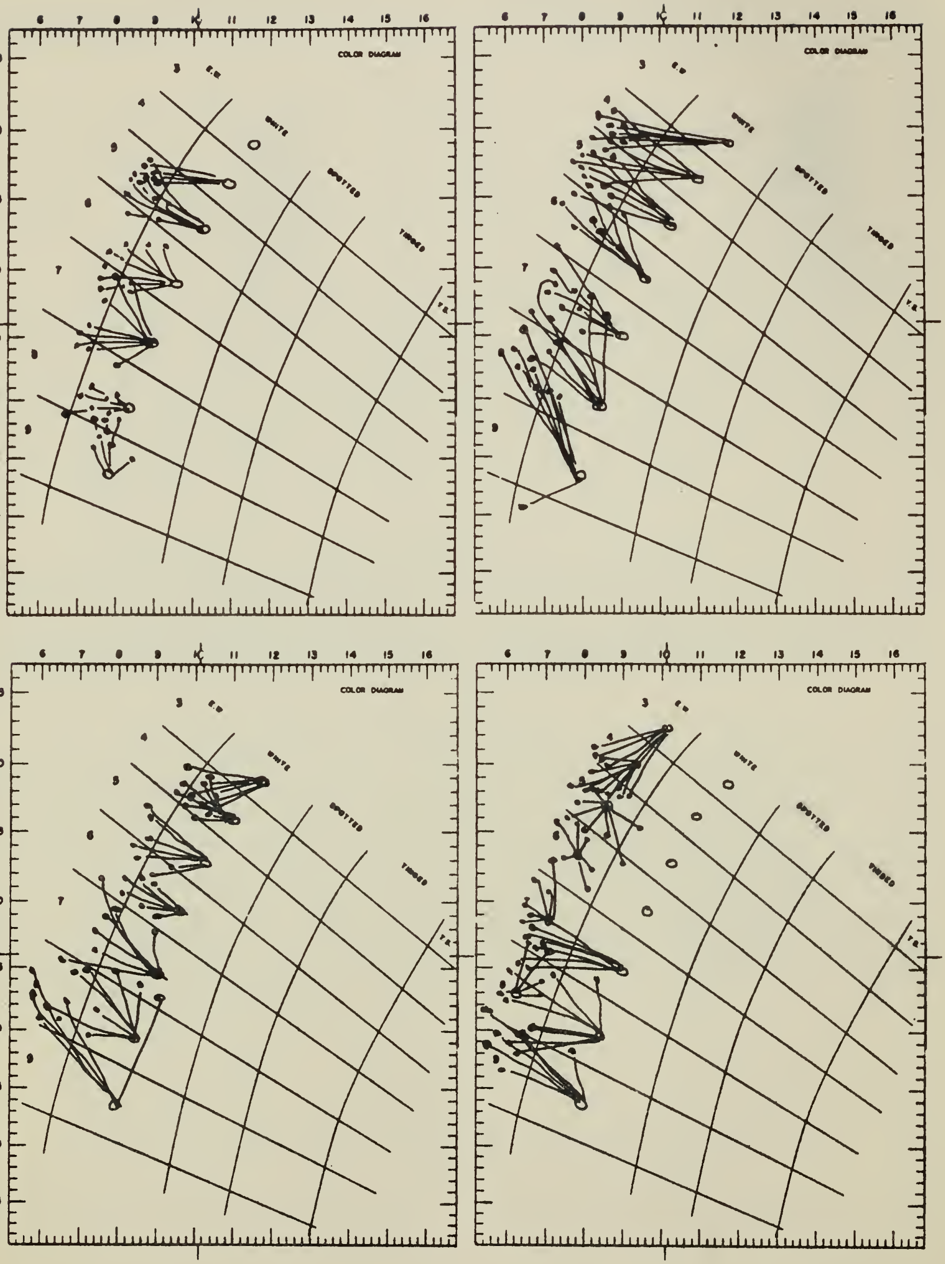


Figure 10.--Representative sets of White grades of cottons from 4 of 26 classing offices, one set representing each of the following areas: Southeast, South Central, Southwest, and West. The grade diagram is based on the 1946 standards measured in terms of Hunter's R_d (vertical scale) and +b (horizontal scale).

Natural Standard Needed

A proposal for one other major change--one that affects the color measurements, particularly in the higher grades--was directed toward a natural instead of an artificial standard. This proposal was sponsored by the standardization group, 10/ and was based on a common sense approach to standards for which many representatives of the cotton industry already had asked. The natural standard would apply to the higher White grades, in particular, inasmuch as prior to 1952 the smooth preparation of standards for top grades was almost entirely manufactured. In fact, in order to provide the smooth preparation and bright color of grades Strict Middling and above, it was even necessary to comb the lint for some of the samples. To prepare Good Middling and Strict Good Middling standards, it was necessary for years to buy old crop cotton, and then work it up by artificial smoothing.

Everyone agrees in principle to the use of a natural standard, but the fact that this entails certain restrictions is not always realized. Use of a natural standard, one in which samples are used as they are taken from the bale, means that the concept of a range of reasonable tolerance in leaf and in preparation must be allowed, as well as a tolerance in color. Once a bale is selected for use in the standards, after checking for uniformity throughout for all factors--color, leaf, and preparation--it should be possible without artificial preparation to select from that bale samples to use in a given position in the standards box. This means no combing of fibers, no picking of leaf either to remove, add, or change its position, for such a method provides standards that do not match the natural appearance of the classing samples used in modern commerce. It is preferable to have standards represent, insofar as possible, the natural conditions that exist, so that when commercial classing samples are rolled to the size of a standards sample they can be held beside the standards box and compared with samples put up in a similar natural condition.

CHANGES IN COLOR DIAGRAM FOR GRADE STANDARDS

With a natural standard as the goal and on the basis of the survey results, a new color diagram of the grade standards was drawn. The change from the old to the new diagram is illustrated in figure 11.

10/ Proposed, and urged throughout the conferences that followed, by the chief of the standardization section, H. C. Slade, Cotton Branch, Prod. Mktg. Admin., U. S. Dept. Agr. Long experience with standards led to the proposal, which could be offered only at a time when "new" standards were to be adopted, since usual conferences are for the sole purpose of approving copies of standards already promulgated.

Lines Separating Color Classes

Because no definite color distinction was found between cottons classed White and Extra White, this division was omitted on the new diagram. The line separating the White and Spotted grades was moved toward the White side, its exact position being drawn on the basis of the best line between the average of the White and of the Spotted samples in the surveys. There always has been an overlapping of color in any series of samples classed, and on the basis of all the available data the best fit was selected. This means that a certain number of samples classed White will measure in the area marked Spotted on the chart, and vice versa. Cottons classed Light Spotted, as may be noted from the survey results illustrated in figure 9, overlap the White grade samples.

The Spotted samples fall largely into areas that on the old chart were marked White; with the line moved over for the White, Spotted cottons now fall in the general range indicated for Spotted on the new diagram. The line separating Spotted and Tinged cottons was moved over slightly, to take into account the overlap between Spotted and Tinged bales, and the line between Tinged and Stained cottons was straightened up somewhat in the higher grades.

Lines Separating Grade Levels

The lines separating the grade levels were left as they were, except that it was necessary--in order to take care of the rougher preparation in a natural standard--to lower the upper limit for Middling, and both of the limit lines for Strict Middling. When a cotton in the higher grades is artificially smoothed, it appears to be brighter, and it measures higher on the chart than it does in its natural preparation. The change in level for these limit lines is not a lowering of the standard, it merely takes into consideration the use of a natural, instead of an artificially prepared sample.

It might be noted that even with these lines lowered, little cotton is found in which the fiber color varies much in grades above Middling. Although it is possible to get cottons that provide a good color step between the Middling and Strict Middling standards, it has not been possible to find cotton in any crop since 1949 that in its natural preparation would provide a full color step above Strict Middling. There is much cotton called Good Middling, but this is not a full step in color above Strict Middling. Any standard made for Good Middling must therefore be Good Middling for leaf and preparation only, or it must be prepared with an artificially smoothed surface to take out shadows present in the same sample as it comes from the bale in its natural state.

New Diagram Tested by 1950 Survey Samples

For testing as well as preparing the new color diagram, samples from the 1950 survey were used. From each of the White and Tinged grades submitted from the 26 classing offices, 36 samples were selected. This number was necessary in order to allow for preparation of two sets of 12-sample boxes, and two sets of 6-sample boxes for use as demonstration sets of the proposed new standards. Samples were selected to represent four general areas of cotton growth. Usually the whitest cotton came from the West, the next whitest from the South Central area, then the Southeastern area, and the yellowest cottons from the Southwestern area. In the White grades, out of 6 samples for each box, it was the purpose that one each be obtained from the West and Southeast and two each from the Southcentral and Southwestern areas. Figure 12 shows a color plot of the samples used. From these samples the sets shown at the various meetings in 1951 were prepared.

In this work with survey samples there were no bales from which to get duplicate samples. For trash measurements it was necessary to rely on samples as nearly duplicates of those selected for use in the standards as was possible. Trash measurements by use of the Shirley Analyzer are reported in a later section of this report. 11/ These measurements were made on samples selected to average close to the samples illustrated in figure 12. Samples of this kind were used in 1951 in order to obtain trash measurements to illustrate what was proposed, so that there might be a basis for discussion without the necessity for bale purchases.

At this point it may be well to point out again the fact that all samples in the survey were visually classed and reclassed, and the grades were well established before a single sample was measured on the colorimeter. After selection of grade samples the colorimeter was used to help make uniform steps between the grades, and to avoid any overlapping in the standards. Use of the colorimeter was, however, a great help to the experienced classers who made the final decision regarding samples to be used in the final sets. 12/

The sets that were shown all over this country and abroad in the summer and fall of 1951 were made from the samples shown in figure 12. Although a number of suggestions were made, on the whole the sets were approved as guides for preparation of a final standard to be submitted for adoption as a "new" standard.

11/ See tables 1 and 2, pp. 23-24.

12/ Sidney Holman of the Memphis Appeal Board, worked full time on this project. He and the author, under general supervision, and with the very close and constant cooperation of H. C. Slade, in charge of the standards work, themselves made up in Washington all the sets prepared from the 1950 survey samples.

1952 Standards Prepared Against New Diagram

Immediately following the last of the 1951 preliminary meetings with representatives of the cotton industry, plans were made to procure and assemble bales of cotton for producing standards covering the general range of the sets shown and approved in the 1951 meetings; no bale was to be considered for purchase that was not already commercially classed as the grade (White, at least) would contain samples representing several of the cotton growing areas.

Samples were requested from shippers for Middling--or for some other grade--and from these, samples were selected that looked satisfactory to Cotton Branch classers for all three grade factors. Such samples were then measured for color, and those that fell within the recommended range for color were further selected on a basis of trash measurements. These trash measurements were made on the Shirley Analyzer both on purchase samples and on samples taken from the bale after its purchase.

Figures 3 to 5 indicate the goal set for color distribution and the result attained in the spring of 1952 when the samples were in preparation for the standards. Figure 13A illustrates, on a copy of the new color diagram, the 6-sample set (No. 30) that was shown at the conference in Washington in June 1952. Because the definition of the standards requires a single set as an "Original," that set would have been the original (unless another selection had been made from the many prepared from the same bales) had a 6-sample set been adopted. However, a 12-sample set was preferred and this set is illustrated in figure 13. Two sets, selected at random, were combined to make this 12-sample set, adopted in 1952 as the new "Original Standard," effective August 15, 1953.

With these standards promulgated, the new diagram should replace the old diagram on the Cotton Colorimeter. Actually, grades as they are being classed currently agree much better with the new diagram than with the old, because current cottons fit better on the new standards than on the old. As far as the grading of White cottons goes, there will be no change necessary from current practice. In regard to Spots, Grays, and Tinges, use of the new diagram should make it possible to obtain better agreement on classification of these grades than obtained heretofore, for even though Spotted grades were not adopted in physical form, the descriptive language of the standards provides that they come between the White and Tinged grades, as is indicated on the diagram.

The Tinged standards adopted in 1952 govern leaf as well as color. From observation of the surface of standards for Tinges, they do not appear to have as much leaf as do White grades of the same name, yet from measurement the Strict Middling Tinge averages more leaf than that expected of Strict Middling White, although at Low Middling Tinge the average is about the same as that expected for the Low Middling White.

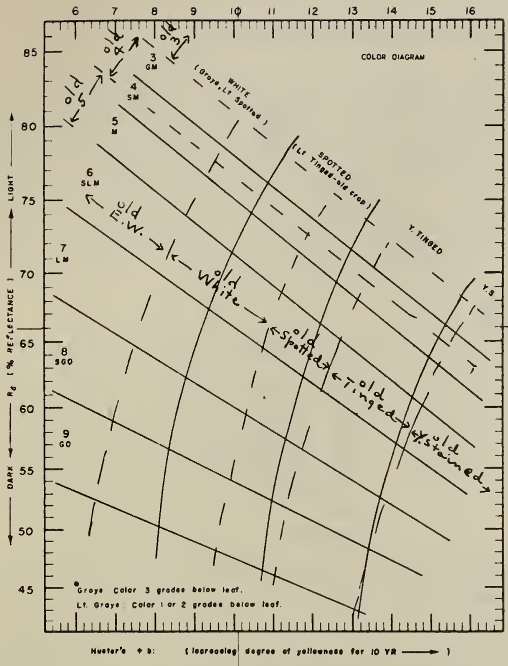


Figure 11.--Color diagram based on old and new standards. Broken line is diagram based on 1946 and 1950 standards, solid line on new 1952 standards.

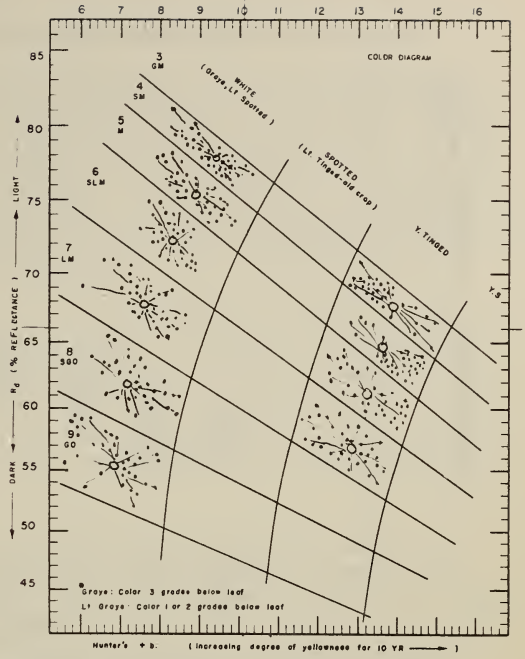


Figure 12.--Samples submitted by 26 classing offices in 1950 survey used to make preliminary boxes shown to representatives of the cotton industry in 1951.

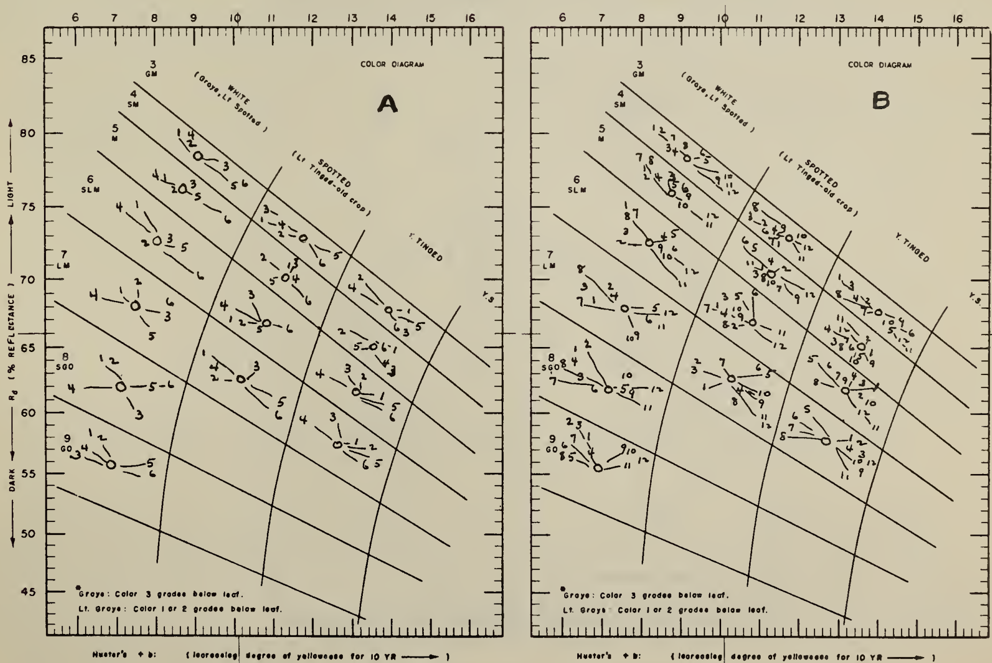


Figure 13.--Sets representing standards as proposed and adopted, shown on new diagram for color. A. 6-sample set; B. 12-sample set.

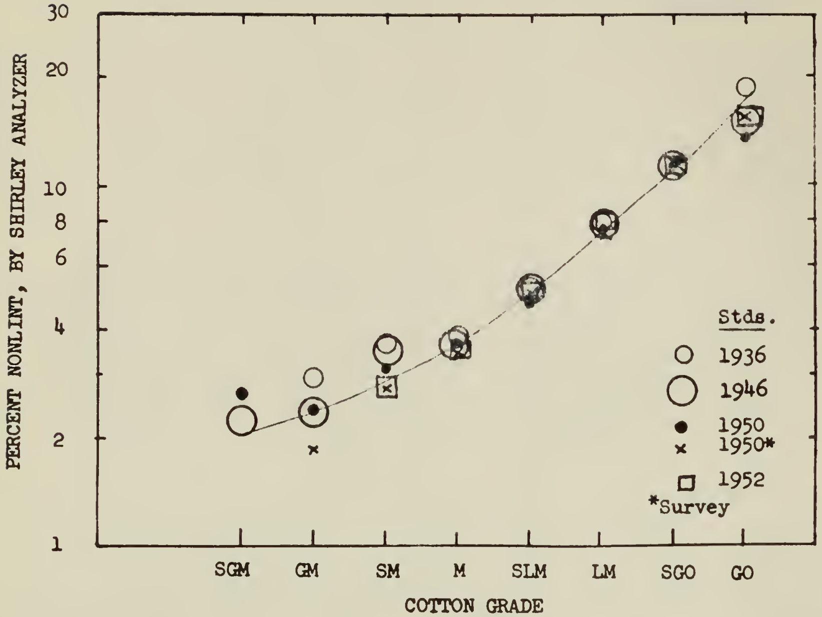


Figure 14.--Trash analysis for bales used in standards since 1936.

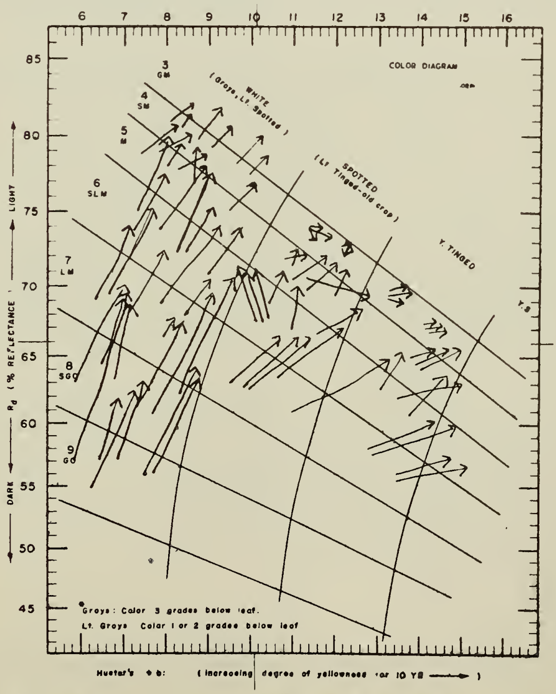


Figure 15.--Color of samples from bales in the 1952 standards, before and after cleaning on the Shirley Analyzer.

Trash Measurements on Bales for Standards

Figure 14 shows trash measurements for bales used in previous standards and in the White standards promulgated in 1952. There was no intention of changing the trash content from previous standards; the measurement goal was the average curve of nonlint in previous standards, the range to extend halfway to the next grade, but allowing no overlap. As stated elsewhere, measurement of trash on the Shirley Analyzer is not a cure-all--many things have yet to be learned concerning trash measurements. But at the present time it is the only measurement of trash [13/] available for use in conjunction with visual judgment.

By visual observation as well as by measurement there was every intention of keeping to the level of trash in previous standards. However, the method of preparing a "natural" instead of an artificial standard--in which leaf particles are placed on, or brought to the surface of each sample, and even added so that the sample will look like the photograph--makes the new standard look different. But the trash is there, and it shows to the same extent that it would show in a hand sample as it is classed from the bale.

Table 1 provides data on measurements of nonlint content for the White grades for these and previous standards, and for recent surveys. Detailed data for trash in the 1951 and 1952 surveys will be presented and discussed in a separate report.[14/] For general information a summary of such measurements as are available for nonlint content of white and colored cottons is shown in table 2. This includes measurements of trash content in the Tinged bales used in the standards for grade that were adopted in 1952.

Table .--Percentages of nonlint content of White grades by measurement on the Shirley Analyzer for bales used in preparing sets of grade standards in 1936, 1946, 1950, and 1952 and for grade surveys in 1947, 1950, 1951, and 1952.

White grades	Percentage of nonlint								
	From average curve[1/]	From bales used in standards--				From grade surveys in--			
		1936 Av.	1946 Av.	1950 Av.	1952-3 Av.	1947 Av.	1950 Av.	1951 Av.	1952 [2/] Av.
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
SGM---	2.0		2.3±0.3	2.7±0.7				1.6	
GM----	2.4	2.9±0.8	2.4±0.3	2.4±0.3		3.5	1.8	2.2	2.1
SM----	2.9	3.6±0.4	3.5±0.7	3.1±0.5	2.7±0.3	4.0	2.7	2.3	2.3
M-----	3.7	3.8±0.4	3.7±0.2	3.6±0.6	3.5±0.3	4.6	3.5	3.2	3.2
SLM--	5.1	5.4±0.7	5.1±1.3	4.7±1.1	5.2±0.7	5.5	5.1	4.3	4.7
LM----	7.6	8.1±1.4	7.7±1.7	7.6±0.9	8.1±1.1	7.8	7.2	6.5	6.9
SGO---	11.0	11.0±2.2	11.2±1.4	11.7±2.0	11.5±1.0	11.0	11.4	9.8	9.6
GO----	17.0	18.6±4.1	15.2±4.2	13.5±2.6	15.3±1.3	15.3	15.4	13.5	11.8

1/ Curve drawn in 1946 on basis of 1936 and 1946 standards data.
2/ Survey for samples classed through December 1952.

13/ Tests for a majority of the samples were made at the laboratories of the Cotton Branch at College Station, Texas, under the direction of Leonard J. Watson, and some tests were made at the laboratories at Clemson, S.C., under the direction of John M. Cook. Special note is made of the speed and efficiency with which Shirley Analyzer test results were furnished by these laboratories.

14/ Refer to footnote 9, page 14.

Table 2.--Summary of measurements for trash content (percent of weight of non-lint by Shirley Analyzer) for cottons prepared for 1952 standards, 1/ for cottons classed in 1945-46 Annual Variety Series, in 1946-48 Standardized Variety Series, and in 1947, 1951, and 1952 grade surveys.

Cottons from--	Color class	Percentage of trash content in--							
		2 SGM	3 GM	4 SM	5 M	6 SLM	7 LM	8 SGO	9 GO
		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Av. Stds. curve	White---------	2.0	2.4	2.9	3.7	5.1	7.6	11.0	17.0
1952 Stds.	White---------			2.7	3.5	5.2	8.0		
	Spotted 2/----			3.2	4.0	6.0	7.8		
	Tinged--------			3.8	4.2	8.3	8.0		
1945-46 Annual Variety Series	Extra White---		1.5	2.3	2.6	3.6	6.4		
	White---------		1.1	2.2	2.8	4.0	6.6	8.5	
	Lt. Spotted---			2.7	4.0	6.8	9.3		
	Spotted-------					6.8			
	Tinged--------				5.7				
	Lt. Gray------				4.0	4.4			
1946-48 Std. Variety Series	White---------		3.6	3.7	3.8	4.9	5.9	10.2	
	Lt. Spotted---		4.3	4.1	3.6				
	Spotted			4.1	4.7	8.0			
1947 Grade Survey	Extra White---		3.5	3.6	5.1	5.5			
	White (reg.)--		3.5	4.0	4.6	5.5	7.8	11.0	15.3
	White (+)-----				4.0	5.4	7.6	10.7	11.4
	Lt. Spotted---		5.1	4.3	5.4	7.2	10.2		
	Spotted-------		4.4	5.3	5.7	6.7	9.8		
	Tinged--------			5.5	6.6	8.2	9.3		
	Yellow Stained			6.4	8.3	11.3			
	Lt. Gray			4.9	5.1				
	Gray			4.4	6.0	7.2			
1951 Grade Survey	White (reg.)--	1.6	2.2	2.3	3.2	4.3	6.5	9.8	13.5
	White (+)-----				3.1	4.2	6.4	8.8	
	Lt. Spotted---		2.7	3.5	4.3	5.8	7.3		
	Spotted-------		2.3	3.7	4.5	6.1	10.2		
	Tinged--------			5.0	6.0	6.5	10.0		
	Yellow Stained				7.6	7.5			
	Lt. Gray------		2.0	2.8	4.1	4.9			
	Gray----------			3.6	3.9	5.2			
1952 Grade Survey 3/	White (reg.)--		2.1	2.3	3.2	4.7	6.9	9.6	11.8
	White (+)-----				2.8	4.4	6.3	10.1	17.1
	Lt. Spotted---		2.4	3.2	4.4	6.3	7.7		
	Spotted-------		1.4	3.5	4.9	6.5	9.4		
	Tinged--------		2.3	4.8	5.0	7.3	7.5		
	Yellow Stained			5.7	8.1				
	Lt. Gray------		2.7	3.1	3.9	6.6			
	Gray----------			2.7	3.9	3.9			

1/ See table 1 for standards prior to 1952.
2/ Not promulgated, given for Spotted cottons prepared in 1952.
3/ Survey for samples classed through December 1952.

Color Measurements After Trash Removal

Color measurement of samples after the trash was removed is illustrated in figure 15 for bales of cotton used in the standards for grade. The measurements indicated by the arrows are of lint, with at least 99 percent of the trash removed. Only a few weeks elapsed between the before-and-after measurements. The original measurement, indicated by the heavy dots, represents the sample with trash included. The apparent improvement in color was caused by trash removal. The lint color is the same in both cases, but the colorimeter measures the average color of whatever sample is placed on its window, therefore, if trash is included in a sample, the instrument averages the trash color and the lint color, with whatever preparation the sample may have.

Samples not selected for standards could vary considerably from the results shown in figure 15. For example, very trashy samples may have cotton relatively brighter than normal, and the lint may show up with greater improvement. Other samples may show less improvement in color, for example, when the trash content is less than would usually be expected for a given grade. Bales represented by such samples would be rejected for use in preparation of standards for grade.

USE OF COLORIMETER IN MEASURING COTTONS OTHER THAN THOSE USED FOR STANDARDS

Preparing the Sample for Measurement

In discussing the measurement of cotton samples put up for grade standards, there are certain facts that should be kept in mind. First, only White and Tinged cottons are adopted as standards in physical form; all other standards--those for Spotted, Yellow Stained, and Gray cottons--are descriptive. Second, samples selected for use in the standards are taken from bales selected to be uniform, and with all three grade factors--color, leaf, and preparation--normal for the grade. Third, samples put up for the standards are prepared in a regular size of carton, with about the same quantity of cotton in each sample, which means that a uniform method is possible for handling the sample for color measurement. Samples are measured in the carton, which is placed upside down on the colorimeter, with a 5-pound weight on the bottom to provide uniform pressure while the sample is being measured.

Since the color diagram is based on measurements made in that way, then cottons for which samples are prepared and measured in the same way should provide directly comparable results.

When it does not seem necessary or feasible to prepare samples as they are prepared for the standards, then a hand sample, if it is large enough to provide an opaque sample, may be placed on the colorimeter directly, without inserting it into a carton. The 5-pound weight (provided with the instrument) should be in place when such measurements are made. If samples are handled and prepared in a consistent manner for all measurements, results will be consistent, and the tolerance for individual measurements can be ascertained. But if the method of sample preparation, and its placement on the colorimeter is inconsistent, then a greater tolerance must be expected in measurements. Sometimes the weight of a hand is sufficient, but it should be remembered that variation in the pressure applied makes a difference in the result.

It should be remembered also that the instrument sees what is placed on the colorimeter window, no more and no less. If there are several extra pieces of trash on the sample face, the measurement will include them, and the result may not be correct for the sample as a whole. In other words, one should make sure that the cotton face placed on the colorimeter window for measurement is representative of the sample for all grade factors--color, leaf, and preparation.

White Cottons

By definition the grades of White cottons--Strict Middling through Good Ordinary--"shall be American Upland cotton which in color, leaf, and preparation is within the range represented by a set of samples in the custody of the United States Department of Agriculture...in a container marked 'Original Official Cotton Standards of the United States...effective August 15, 1953'." This set of samples is represented in figure 13B.

The range in White cottons includes what was formerly called Extra White, a term that has not been a true color description for many years. The term "Extra White" has been applied to cottons classed in the Western area and grown under irrigation, but the color range of cotton in that area overlaps the color range for cottons from other areas. Cottons from the Mississippi-Arkansas area often are as white as cottons from California; the color range overlaps. There is, however, enough consistency in the average color from each area so that in setting up the regular diagram shown in figure 3 the goal in the White grades was that the circle at the extreme left of each group should indicate the whitest sample, which would be obtained from the Western area (California-Arizona-New Mexico, etc.), samples indicated by the next two circles would come from the South Central area (Mississippi-Arkansas, etc.), and the other circles would indicate samples from the Southeast and Southwest. Usually cottons from the Southwest (Texas-Oklahoma) average the yellowest in color, but in all areas individual samples show considerable overlap.

Average color for grades of White and Tinged cottons classed in four areas for three consecutive surveys is shown in figure 16.

The fact that on this figure averages of grades as classed do not spread as wide as the standards indicate they should is owing to a psychological factor that is hard to overcome in any sensory grading. Within any group of samples, the top samples appear better than they are, and bottom samples appear worse than they are. This tendency occurs whenever grading is done by any sensory process, whether sight, hearing, touch, taste, or smell. It is an "end effect," and can be expected for the grading of samples in any general survey. Taking this into consideration, it can be seen that classification of the White grades--at least for the last several years--has followed the pattern of the new White standards.

Since this is true, the colorimeter can succeed in aiding the classer in placing samples in the right grades very accurately once he finds a sample to be White, with color, leaf, and preparation normal for the grade.

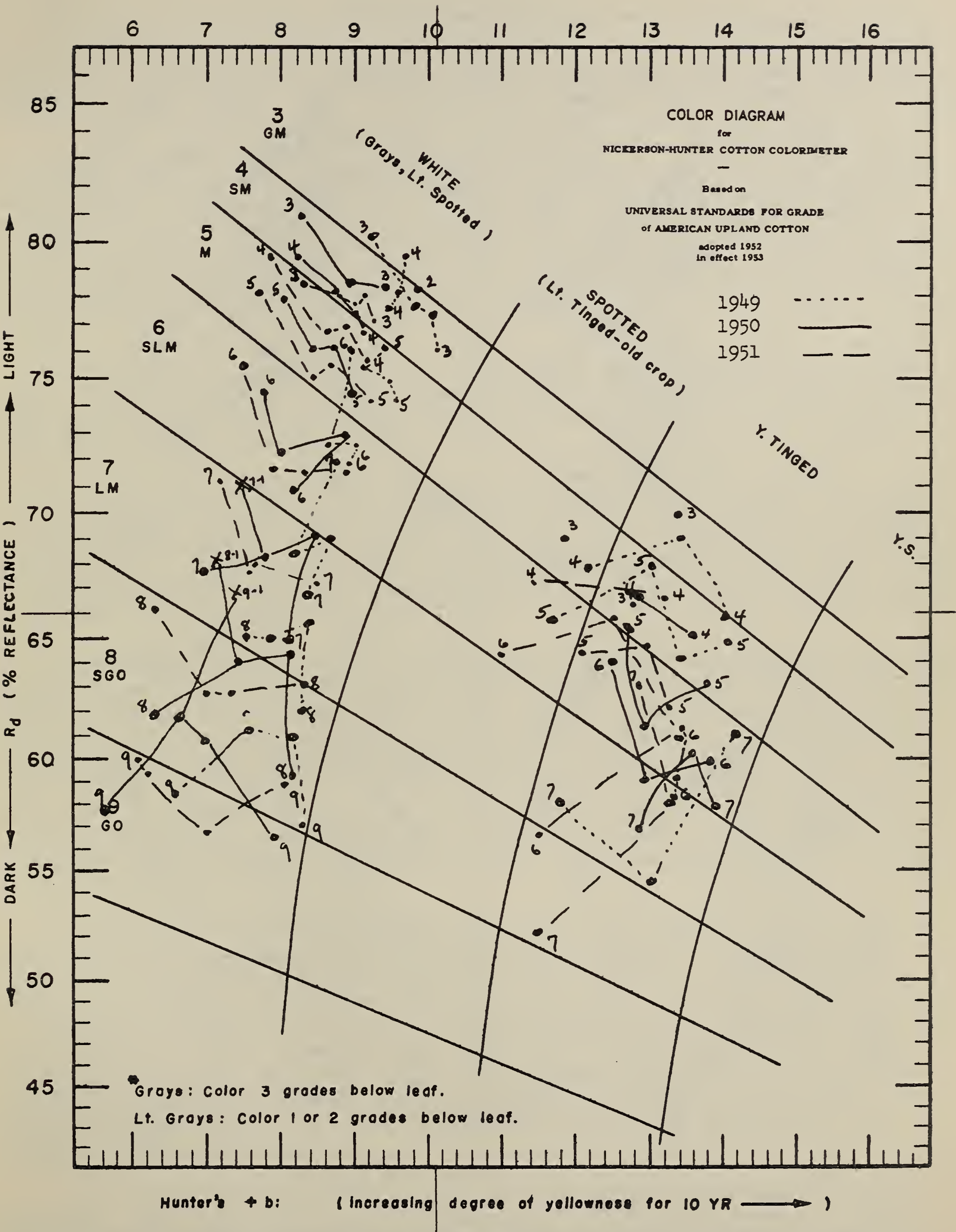


Figure 16.--Heavy dots indicate averages of 1949, 1950, and 1951 survey results for grade of White (and Extra White) and Tinged cottons from four cotton growing areas. Grades, indicated by number, are shown each year for four areas whenever that many areas were represented.

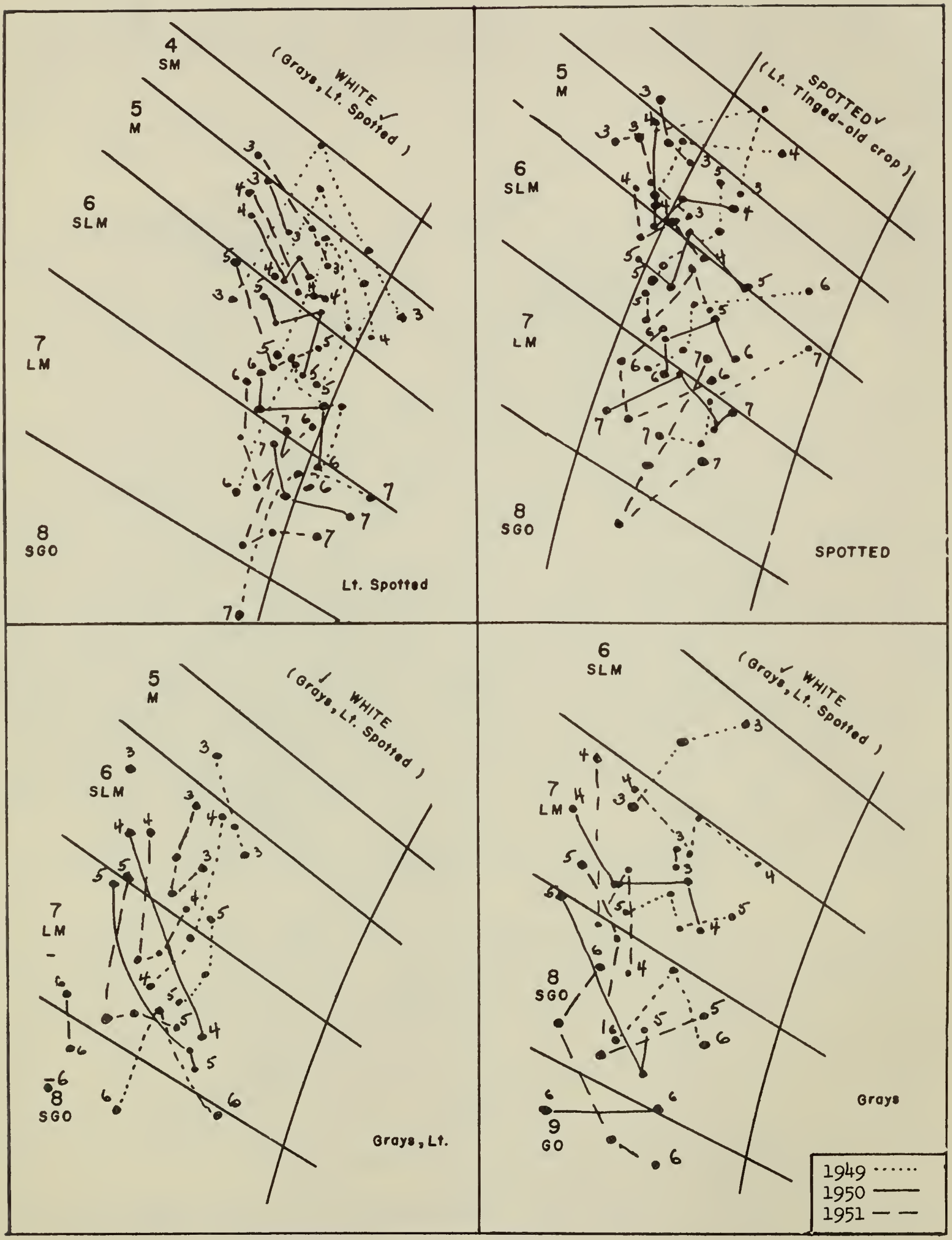


Figure 17.--Heavy dots indicate average color of grades classed in four classification--Light Spotted, Spotted, Light Grays, and Grays--for three surveys: 1949, 1950, 1951. Background diagrams are from full diagram based on the new standards, enlarged portions shown for each color class. Grades, indicated by numbers, are shown each year for four areas whenever that many areas are represented.

Spotted Cottons

The definition of descriptive standards for Spotted cottons states that each of the grades shall "in spot or color or both" lie between the White and Tinged grades of similar grade name (leaf and preparation as in the White grades).

Use of the colorimeter in judging Spotted cottons is much easier with the new standards diagram than it was with the old, for now that the standards diagram shows the White and Tinged cottons where they should be, the Spotted cottons will--on the whole--have an average color that will measure between the color of the White and Tinged, which is the range required by their official definition. In the past the higher grades of Spotted cottons have not always been called strictly as required by the standards, with color or spot, or both, between the White and Tinged grades of the same name.

In figure 17 survey results for four areas in each of three years are given for the average color of cottons classed Light Spotted, Spotted, Light Gray, and Gray. Each is shown on an enlarged portion of the full diagram in order that details may be followed.

Reference to the data for cottons classed Light Spotted shows that with few exceptions, the average color for Light Spotted cottons is about the same as the average color for the White grades. There are a few averages that cross the line set up to divide the White and Spotted grades, but it may well be that on a further classification such samples would be called a true Spotted, instead of a Light Spotted cotton.

Reference to the diagram for the cottons classed full Spotted shows that except for some of the higher grades which overlap the color of the average background for White or for Light Spotted, most of them fall into the area between White and Tinged on the diagram for the new grade standards. Again, there is an overlap, but perhaps on a reclassification it would be found that some of these cottons would be more accurately classed as Light Spotted. Some overlap always can be expected for line bales, but once the classer decides whether the background color is White or true Spotted, it should be easy to keep uniform lots of cottons by using the colorimeter to differentiate between a Light and a true Spotted cotton.

As for the grade levels, the higher grades of Spotted cottons show a wide difference in interpretation. What may be called Good Middling Light Spotted in one cotton classing area may be considerably below the average color of Good Middling Light Spotted in another area. It would be much simpler to identify Light Spotted cottons as those having the same background color as the White grade of the same name, but with too much spot to be called White. According to present practices many cottons are called Strict Middling Light Spotted that have a background color of Middling and a trash measurement of Middling. (See table 2 for trash measurements on cottons in several crops classed as Light Spotted.)

For Spotted cottons there is also a considerable difference in interpretation. The color that one area identifies as Middling Spotted, another area might call Strict Middling Spotted, and what another area calls Middling Spotted might be called Strict Low Middling Spotted by still another area. If

the cotton is referred to the standards, it must by definition lie between the color of the White and Tinged grades of the same name.

The sets proposed for Spotted grades as part of the 1952 standards fall into position according to this definition, as is shown on figure 13. The trash measured for bales in these standard grades was slightly greater than for bales in the White grades, but not nearly so great as in cottons classed in the several surveys (see table 2). When the grades get down to Low Middling Spotted more of the classifications measure where they should on the diagram, although two of the averages in figure 17 seem high, and one seems too low.

The kind of spot, how it will distribute itself in a mix, is an important factor to be considered. From a study of figure 15 which shows the color of the mixed lint after separation of trash by the Shirley Analyzer, leaving a well blended sample for measurement, it may be noted that Spotted and Tinged cottons do not always show the general color improvement shown by the lint in the White grades. A few samples tend to show it, but many of them show a deepening of color as the spot is mixed throughout.

Studies of the color of lint resulting from Spotted and Light Spotted cottons can reveal to a cotton buyer a great deal about the usefulness of such bales in his mill. Those cottons that clean up to show color improvement--of the type evidenced by the cottons in the White grades--should be of considerably more value than cottons classed in the same Spotted grades but which will not blend to produce a lighter color when trash is removed.

Tinged Cottons

By definition the grade of Tinged cottons is that shown by the range represented in the sets of samples held as Originals of the standards for grade. The wording for the Tinged standards in the 1952 promulgation follows that for the White grades. For the first time, the boxes of Tinged grades represent all grade factors, not color alone as heretofore.

Figure 16 shows the range of averages for classification of Tinges in three surveys, 1949-51. The discussion regarding end effect in calling the highest samples higher than they are, and the lowest samples lower than they are, holds for these grades as well as for the Whites. Survey results for White and Tinges are shown on a single diagram because these are the only two color classes for which standards are available in physical form. Samples classed as Tinged should, therefore, show greater consistency than those for grades that are descriptive only.

Yellow Stained Cottons

Cottons described as Yellow Stained are those which in leaf and preparation are similar to Tinged grades of the same name but deeper in color.

No diagram is shown for the samples graded Yellow Stained in the 1949, 1950, and 1951 surveys because so few samples of these descriptions were available. However, it may be said that the color classification of Yellow Stained

is borne out by colorimeter measurements. The grade levels varied considerably from year to year; in one year the color called Middling Yellow Stained might be high, in another year low. Except for actual samples, laboratory measurements provide the only means of learning what to expect of cottons of these grades.

Gray Cottons

Grades for Gray cottons are descriptive. In the order of promulgation Grays are described as equal in leaf and preparation to the White grade of similar name, but "more gray in color" and "no darker in color than the dullest bale" in the grade three grades below.

There always has been a great variation in the color of samples called Gray. But use of the colorimeter has made it possible to pin the Grays down with very little trouble. In fact, the first time that there was full agreement by Cotton Branch classers on a set of types to represent Grays and Light Grays was after their preparation by use of the colorimeter. On the basis of many classifications it was found that agreement could be reached if cottons three grades different in leaf and color were called Gray, and cottons two grades different were called Light Gray. For cottons called Light Gray when the color is only one grade below the leaf content, it was suggested that classers think of them as "very Light Grays" to distinguish them from the more usual Light Grays found in other classing areas. The entire color range covered by the Gray samples is so great for a single grade name that the only way consistency of classification can be maintained is to think of them in this manner.

A classer with a colorimeter should find it very simple to grade Grays consistently. If a sample measures in the block indicated as Low Middling White, the classer must look at it and judge its leaf. If the leaf and preparation are Low Middling, then obviously the bale will be called Low Middling. If the leaf and preparation are Low Middling, and the background spotted it will be Low Middling Light Spotted. But if the leaf and preparation are Strict Middling, he should call the sample Strict Middling Gray, for in color it is three grades below its leaf and preparation. If the leaf and preparation are Middling, which is two grades above the color, he should call the sample Middling Light Gray.

There are a few cases in which the color may be even lower than three grades below the trash content, in which case the sample may be much like those formerly graded as Blue Stained. Only a few such samples occur each year, but if the color is as low as Good Ordinary, and leaf content equal to Middling, this would mean four grades difference, or what might formerly have been graded as Light Blue Stained, whereas Strict Middling leaf for the same color would be equal to five grades between leaf and color, or the old Strict Middling Blue Stained--no longer included in the standards.

Even without a colorimeter the classification of Grays will become much more consistent if color and leaf factors are judged separately and their difference noted in accord with the above illustrations.

The new grade diagram indicates the overlap expected in the color classifications, as between White, Light Spotted, and Grays.

Combinations Not Within the Standards

The standards provide also for grading of cottons in which the color, leaf, and preparation are within the range of the standards in the several classes described, but which contain a combination of those not within any standard described. In that case the grade "shall be designated according to the standard which is equivalent to, or if there be no exact equivalent, is next below the average of all the factors that determine the grade of the cotton: Provided, that in no event shall the grade assigned to any cotton or sample be more than one grade higher than the grade classification of the color or leaf contained therein."

For any such cottons it could be quite difficult to judge the grade. With the colorimeter one can place the color of the cotton correctly, and then go on to judge the other factors separately. It is very difficult for a classer to judge accurately the background color of a very clean sample if he is not used to such cottons. Because it is clean, he is inclined to call the grade better than its color may warrant. As an example, good classers--even when they know that a low grade sample has been through the Shirley Analyzer to clean out the trash--will often call the result equivalent to Good Middling in grade. If there is no leaf, and if the classer is not used to judging color without leaf, the color will look better than it is. But in the mill it will run no better than it is! If it is the color of Good Ordinary, it will still be the color of Good Ordinary when used in the mill, whether the classer recognizes and calls it Strict Good Ordinary or Good Middling Gray, or whether he misjudges and calls it Good Middling.

If any classer doubts this statement, let him look at samples of bales from the standards for grade after they are put through the Shirley Analyzer. Until he does this, the classer usually finds it hard to believe that the color is as low as that shown on figure 15!

This is one of several cases where classers can find the colorimeter a most useful classing aid.

For further discussion of the effect of cleaning on grade and color of cotton, see a report on cleaning published in 1947 (8).

Seed Cotton

In the above-mentioned cleaning report (8), a series of 170 cottons were measured for color first as seed cottons, then as lint cotton, and finally as cleaned lint (lint through the Shirley Analyzer). The results showed that the color of seed cotton can be measured and related to its usual commercial grade, or even to its cleaned lint. Little commercial work has been done along this line, but it is possible and practical, providing a representative sample is used in the measurements.

Cleaned Lint

Studies of cleaned lint--of samples after passage through the Shirley Analyzer--can provide the classer or cotton buyer with a very considerable

amount of useful information. Colored cottons usually result in an allover tinge, in fact, the Shirley Analyzer is a good blender. With color measurements and grade before cleaning, and trash measurements and color after cleaning, the classer is able to obtain an intimate picture of his cottons.

Figure 15 shows color measurements before and after cleaning for cottons used in the 1952 standards. Figure 18 shows a composite picture of "before and after" cleaning for cotton samples from recent surveys.

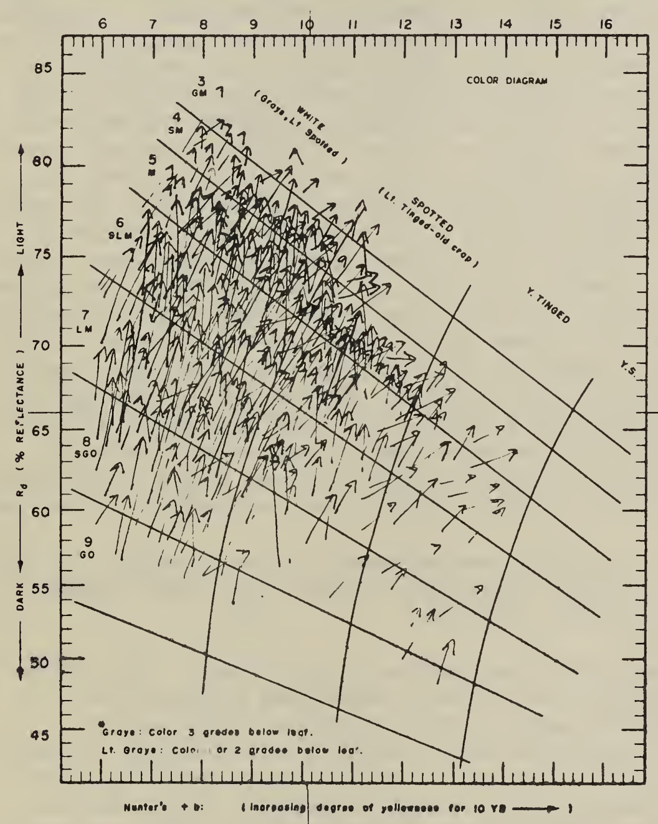


Figure 18.--Composite picture of samples from recent surveys before and after cleaning on the Shirley Analyzer.

Yarn and Fabric Measurements

The colorimeter can be used to follow from raw stock to grey and bleached fabrics. 15/ The color measurements that result at each stage will depend on sample preparation as well as on the color of the fibers.

15/ Because the range of the cotton colorimeter is restricted to raw cotton, the color of many dyed fabrics cannot be measured on it. Reflectance above 35 percent can be measured by disregarding the "b" indicator (which may go off-scale) and reading the R_d scale only. The Hunter Color and Color-Difference Meter may be used to measure the color of any nonfluorescing dyed fabric in terms of the R_d and "b" scales of the cotton colorimeter, with an "a" scale added. The "a" scale indicates the red-to-green component which usually does not vary significantly in the yellowish colors of raw cotton.

Once a particular method of sample preparation is adopted it should be used throughout any single study, otherwise differences in measurement may be caused by sample preparation as well as by fiber color. The direction in which the sample is oriented influences the result; the fibers themselves have gloss; the size and number of twists in a yarn will influence the result.

The color of grey cloth samples will depend on the weave (open or tight), the number of layers (whether enough to be completely opaque), and the sample orientation (at a 90° interval there will be a maximum and minimum). If small differences are important, all factors must be controlled, and samples must be prepared each time in the same manner. At first thought it may seem peculiar that cloth samples made from yarns spun from a particular color of high grade raw stock would measure more color in the cloth sample, with the deepest color for a loose weave and a tight weave measuring closer in color to the raw stock measurements. But it will happen. However, if the construction is held constant, a series can be measured and individual samples will fall into the same pattern relative to each other as in the raw stock, whether the construction be as tight as 80x80 or as loose as 28x24. The looser fabric provides more chance for multiple reflections, and therefore will measure more color than the tighter fabric. Both will measure more color than the raw stock itself. When bleached, if the samples have been washed in a clean bath, and in a clean bleach (so that dirt from the lower grade samples does not find its way onto the higher grade samples--as often will happen when clean and dirty samples are put through the same baths), the final result should show the color in the same order as that in the raw stock, although differences between samples may be much reduced; they will not all bleach to the same white but there will be slight differences even after bleaching, if the bleach is held constant for each sample in the series.

Fabric samples will give different measurements in the direction of warp and of filling; to avoid this, samples sometimes are spun on a wheel for measurement. Or the direction may be held constant.

In figure 19 several measurement problems are illustrated. The differ ence in measurement for grey and bleached fabrics made from different raw stock; differences for measurements made at 90°; differences that may be caused by bleaching treatment; and differences caused by construction or weave of grey fabric. The open circles in figure 19 indicate measurements of grey fabric; arrows indicate measurements with the fabric oriented 90° in its own plane. Bleaching results for two laboratories on the same raw stock are indicated, one in the upper and the other in the lower series of diagrams. The wide difference in results from these two laboratories shows what can happen when samples are handled differently. The samples of balloon cloth show fairly similar results for the two laboratories, except that sample No. 1 was bleached whiter by the first laboratory. Samples of sateen were bleached out very white in one laboratory but were hardly affected by the bleach in the second laboratory. As for the twill, the second laboratory got whiter samples from its bleach than did the first laboratory. In most cases the color of the bleached fabrics is in about the same relation, one sample to another, as in the grey fabric.

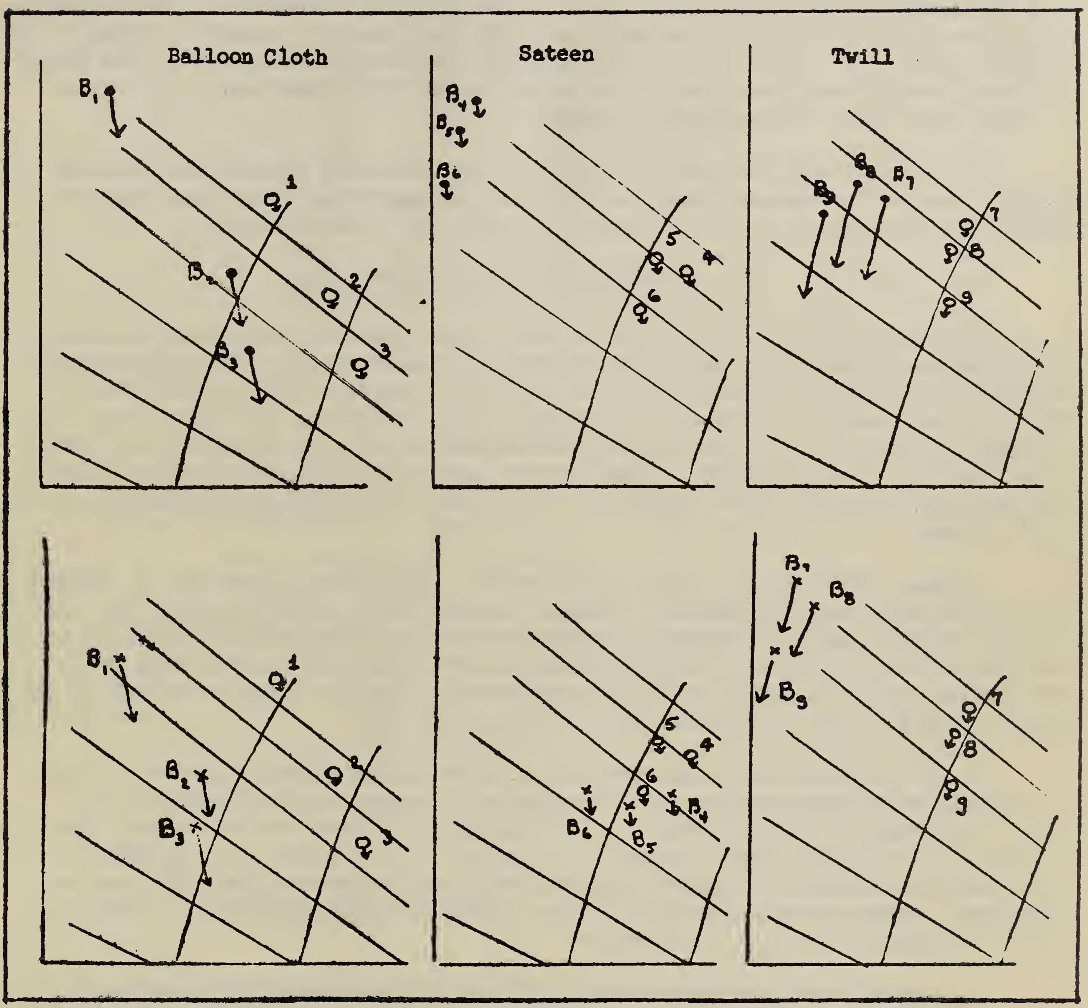


Figure 19.--Fabric made on three constructions, each series from three raw cottons. Open circles, grey fabric; arrows indicate measurements with fabric oriented through 90°. Bleaching results (marked B) in upper and lower series of diagrams indicate results for two laboratories for bleaching of the same grey fabric. The cotton grade diagram in the background provides reference points for comparison of the amount of color change.

Note the wide color difference for 90° orientation for the bleached balloon cloth and twill, compared with the very slight difference for the sateen. Note, too, that these differences are much greater for the bleached than for the grey fabric, except for the sateen. The balloon cloth is a plain weave (1 over, 1 under), 116x124 threads to the inch, warp 86's filling 80's; the sateen weave is 4 over, 1 under (4 of 5 threads on the surface), 85x54, warp 15's, filling 9's; and the twill is 3 over, 1 under to right, 116x56, warp 36's 2-ply, filling 24's 2-ply. About 12 thicknesses were used for each sample measured, the whole being backed with black and with white to make sure that the sample was opaque.

The wide number of variations that can be caused by a difference in fabrics and/or its weave, construction, and sample preparation are factors that must be controlled if consistent results are to be obtained.

CALIBRATION OF THE COLORIMETER

If the grade levels of cottons are to be measured accurately on all colorimeters, each instrument must be kept in calibration. Five papers are supplied with the colorimeter for use as color standards in calibration. These paper standards have a matte surface which provides the advantage that slight differences in angles of illumination will not be important, as they could be for glossy samples. These papers are in the range of cotton colors, and provide excellent test results if the papers are handled carefully, and kept clean.

Often, however, the papers get soiled. Therefore, some way is needed for providing a more permanent standard against which these papers, and the cotton results, may be checked, in order to be sure that the colorimeter is reading correctly when cotton measurements are made. To answer this need, two tests have been added to the Cotton Service Testing items provided by the Research and Testing Division, Cotton Branch (1) (2).

One test provides a set of tile and porcelain enamel standards, and a diagram of their measurements made against a master series held in the U. S. Department of Agriculture. The standards include one color near the center of the cotton color diagram, and other colors toward the corners of the diagram. Each set that is supplied will be checked against the master standard. Measurements supplied to the purchaser will allow him to use his set as standards for his colorimeter.

A second test has been added since it is possible, if the geometry of the lighting on the instrument is not kept constant (for example, if new lamps are not inserted correctly), to get a different level of measurement for fiber samples (into which light may penetrate) than for paper or tile samples (which allow little surface penetration). To avoid a possibility of difference due to this cause, a difference that measurement of tile or paper samples might not discover, a test has been provided that is based on cotton samples. This is in addition to the test that includes use of enamels and tiles.

Because cotton changes color, sometimes more rapidly than at other times, and because the surface condition of the same sample may differ at different times, measurements made for cotton samples can be certified only for the time at which the measurement is made. For those who purchase, or already have purchased, a test set of enamels and tiles, a test is available also for color measurement of any cotton grade standards that may be purchased. Check measurements on enamel and tile standards will be made at the same time that the cottons are measured.

Use of these two sets of measured samples will enable anyone using a colorimeter to make sure that it is operating at the level at which the original Cotton Branch measurements were made and against which the original instrument scales are calibrated. Measurements provided for cotton samples cannot be expected to remain correct for too long, since the color of the cotton will change, and because the surface of the sample becomes smooth and/or dirty after continued handling and remeasurement. The enamel and tiles, however, are reasonably permanent and may be kept clean, so that they will provide at all times--particularly when used in conjunction with the Munsell standard "cotton" papers--a good check for calibration of the colorimeter.

LITERATURE CITED

(1) Cotton Branch.
1952. Cotton Testing Service. Prod. Mktg. Admin. U. S. Dept. Agr. 39 pp. (Processed.)

(2) ______
1952. Regulations and Fees for Cotton Testing. Prod. Mktg. Admin. U. S. Dept. Agr. 4 pp. (Processed.)

(3) Hunter, R. S.
1942. Photoelectric Tristimulus Colorimetry with Three Filters. Optical Soc. Amer. Jour. 32:509-538, illus. Also, Natl. Bur. Standards, U. S. Dept. Commerce Cir. 429, illus.

(4) Judd, D. B.
1952. Color in Business, Science, and Industry. 401 pp., illus. (Publisher Wiley.)

(5) Nickerson, D.
1950. Color Measurements of Cotton. Preliminary report on application of new automatic cotton colorimeter. Cotton Br. Prod. Mktg. Admin., U. S. Dept. Agr. 18 pp. (Processed.)

(6) ______
1946. Color Measurement and Its Application to the Grading of Agricultural Products. U. S. Dept. Agr. Misc. Pub. 580. 63 pp., illus.

(7) Nickerson, D.
1951. Effect of Exposure and Storage on Color and Other Factors of Quality in Raw Cotton. Cotton Br. Prod. Mktg. Admin., U. S. Dept. Agr. 27 pp. (Processed.)

(8) ________
1947. Effect of Cleaning on Grade and Color of Cotton. Cotton Br. Prod. Mktg. Admin., U. S. Dept. Agr. 26 pp. (Processed.)

(9) ________, Hunter, R. S., and Powell, M. G.
1950. New Automatic Colorimeter for Cotton. Optical Soc. Amer. Jour. 40:446-449, illus.

(10) United States Department of Agriculture
1952. Official Cotton Standards of the United States for the Grade of American Upland Cotton, effective August 15, 1953. Title 7--Agriculture. Federal Register (Aug. 5, 1952). pp. 7405, -07, -08.

Washington, D.C. April 1954

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COLOR OF COTTON GRADE STANDARDS, 1909-54 1/

By Dorothy Nickerson, Cotton Technologist

In preparing grade standards one of the important factors that must be considered is color change with time, particularly in the higher grades and in the colored cottons. Some of this has been reported in detail (1), (2), (3), (4), (5), (6) 2/ but to many classers these reports undoubtedly seem fairly technical and somewhat remote from the immediate problem of cotton classification.

In order to bring the matter closer home, and up to date in terms of present standards, the information in the present report has been assembled. The information became available by way of a house-cleaning job, which took place in March 1954. After more than a quarter century of storing sets of sealed boxes passed at each standards conference, space in the vault of the Cotton Division became so crowded that the regulations were changed. Now, in addition to the original set, it is necessary to retain only copies of standards that are current. Before discarding the many early sets that had accumulated, they were taken to the color laboratory for measurement. 3/ Results of these measurements are reported in figures 1 to 4 against a background diagram of the present standards.

The samples illustrated in the first diagram of figure 1 are from boxes of two grades put up in 1909. After 45 years the 1909 Good Middling samples are still up at the level of the Good Middling, and the Middling is well up in the present level of Middling, although both have yellowed until their color now has shifted from White until it averages in the present Tinges.

A series of 1914 cottons from grades 2-Strict Good Middling through 9-Good Ordinary is shown next; these cottons have changed, particularly in the higher grades for which most of the samples are now at least as highly colored as the average color of the present Spotted boxes. The grade levels seem compressed; Good Middling is no higher than the present Strict Middling level, and the Good Ordinary is little different from the high side of the present Strict Good Ordinary.

1/ This report is prepared as part of the program under the direction of John W. Wright, Chief, Standards and Testing Branch.

2/ Underscored figures in parentheses refer to Literature Cited, p.14.

3/ Trash measurements could not be made on these samples, for a great many consisted of faces over fillers that sometimes were not even in the same grade.

The next series, for 1915, shows no greater change in grades 2 through 9 than the series for 1914 showed. But a Middling Fair is included, and it has yellowed considerably more than the Strict Good Middling or Good Middling of the same series, that is, except for one particular sample the surface of which seemed to carry dust or mildew, which accounts for the peculiar change shown by sample 12.

In the 1925 series, a particularly good job evidently was done in making uniform steps between grades. Although the entire series is much yellower now than present standards, and although grades 4 to 7 are almost a grade lower than present grades, the total color range from Middling Fair through Good Ordinary is about the same as in the grade standards of today. This is evidenced by the fact that the Good Middlings, even though they now seem like Tinged Good Middlings, are still well up in the Good Middling block, whereas the 1925 Good Ordinarys measure about as low as the Good Ordinary in present standards. The cottons represented in the 1925 series of figure 1 are at least 30 years old, since they must have come from the 1924 crop to be available for use in 1925, yet the lower grades show no change greater than toward the white side of our present Spotted standards, although the grades Good Middling and above have yellowed enough to equal present Tinged or Stained cottons.

For comparison to these very early sets of U. S. standards, figure 2 shows measurements of two full sets of so-called Liverpool Standards, one dated 1916, the other 1920. In each set there were three series of boxes: American, Gulf, and Texas. Of the 12 samples which were in each box and which were from Middling Fair to Ordinary (1 to 10),4/ six samples were from one bale and six were from another bale. In the 1920 sets of Liverpool Standards many bales seem identical with those used in the 1916 set. It is particularly interesting that the color range of the Liverpool grades in the American series seems the same as that of U. S. standards today. Liverpool's Low Middling is about the level of the present U. S. Low Middling, but the grades above this seem lower than present U. S. grades. Liverpool's top grades, marked 1 and 2, seem to have yellowed no deeper than the present U. S. Good Middling Spots or very light Tinges. The color of grades Low Middling and below is well within the color range of present U. S. boxes. This is true in spite of the fact that most samples from U. S. boxes in the period as early as this seem to be considerably yellower than Liverpool representations of American cottons. 5/

4/ The term "Fully" was used by Liverpool in place of "Strict," so that the names are slightly different than in present U. S. standards. 1, Middling Fair; 2, Fully Good Middling; 3, Good Middling; 4, Fully Middling; 5, Middling; 6, Fully Low Middling; 7, Low Middling; 8, Fully Good Ordinary; 9, Good Ordinary; 10, Ordinary.

5/ It is probable that little change has occurred in these lower U. S. grades, for it is a fact--verified by H. C. Slade, who has been present at standards conferences since 1914--that a preference for "creamy" cottons kept U. S. grade standards on the creamy or yellow side even in the low grades.

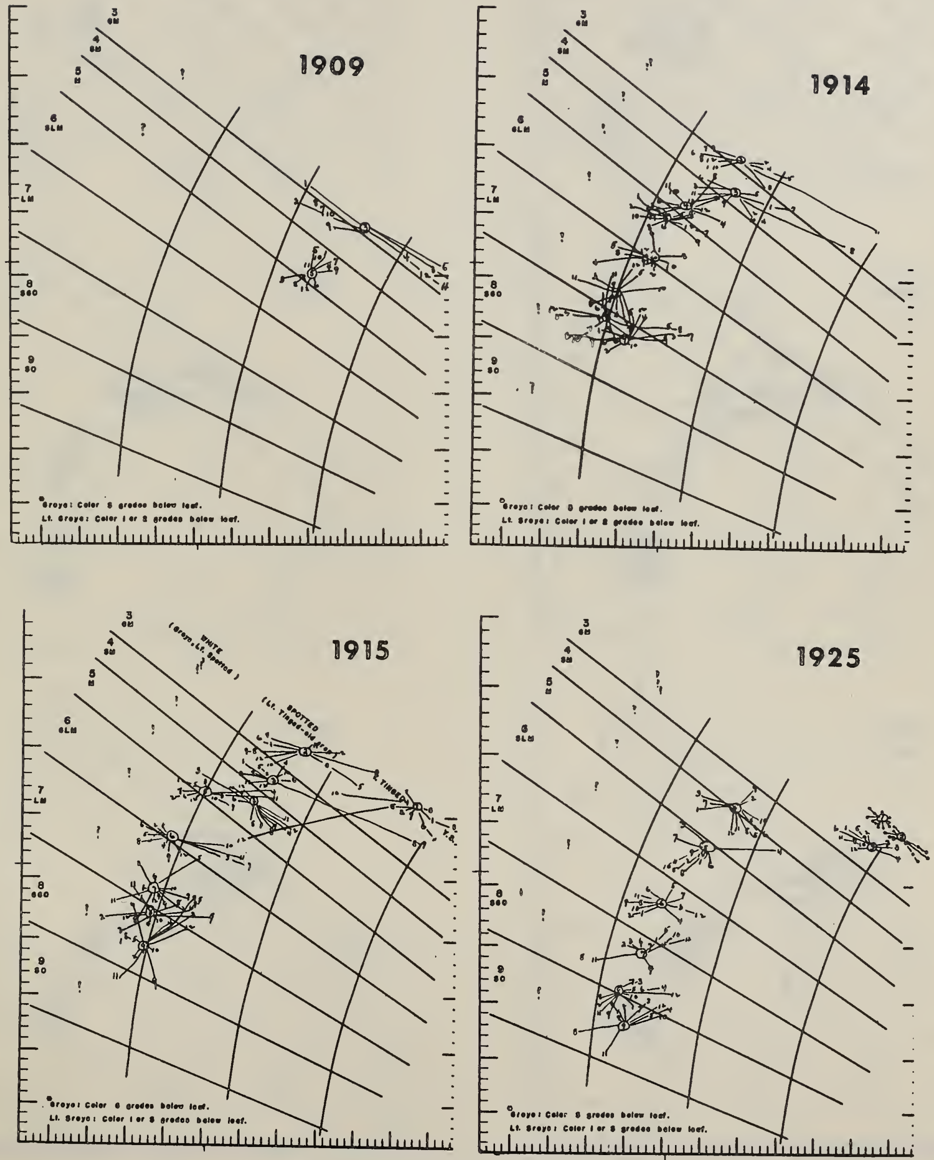


Figure 1.--Color measurements in 1954 of several sets of old white standards packed up and stored since they were passed in 1909, 1914, 1915, and 1925.

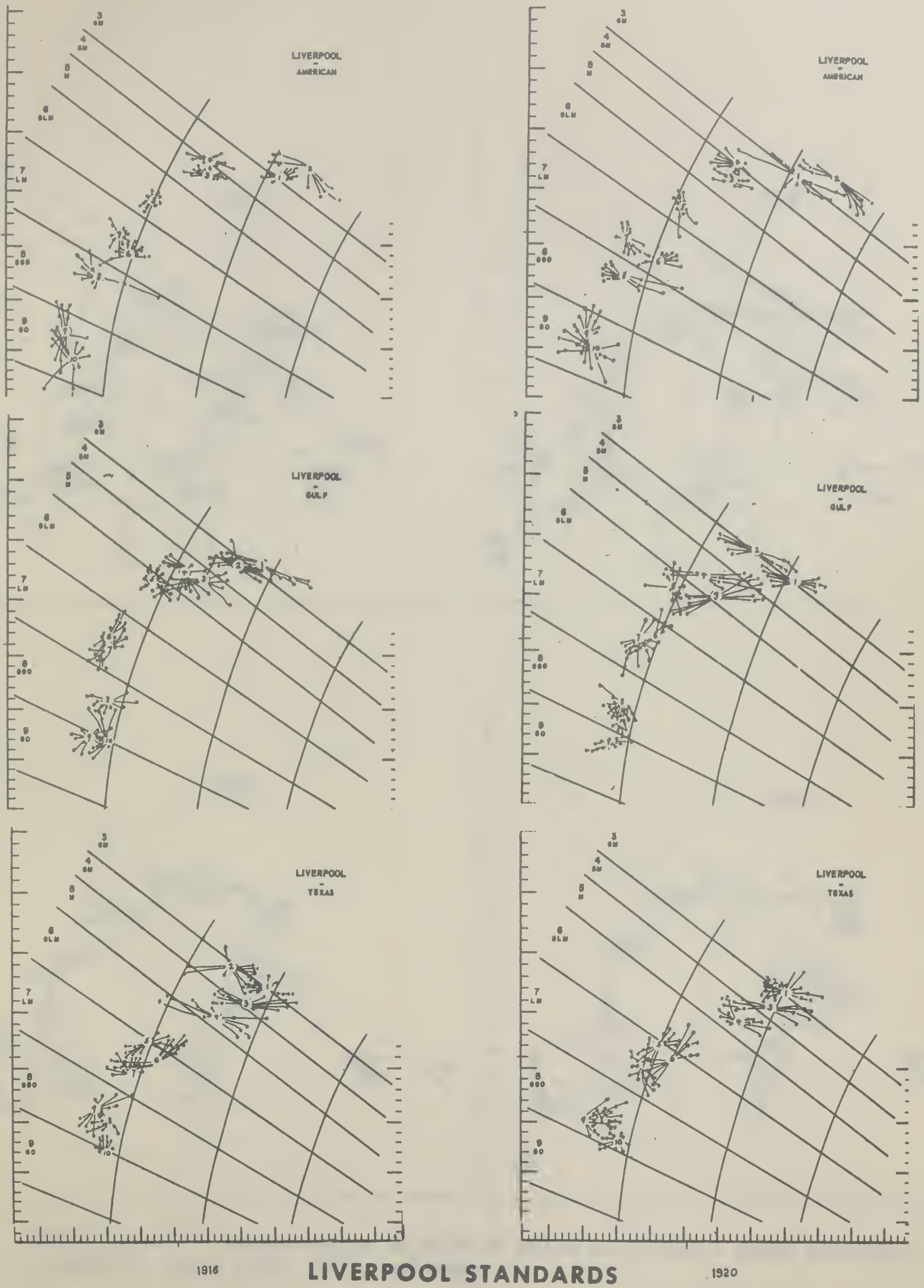


Figure 2.--Color measurements in 1954 of two old sets of Liverpool Standards for American cottons, 1916 and 1920.

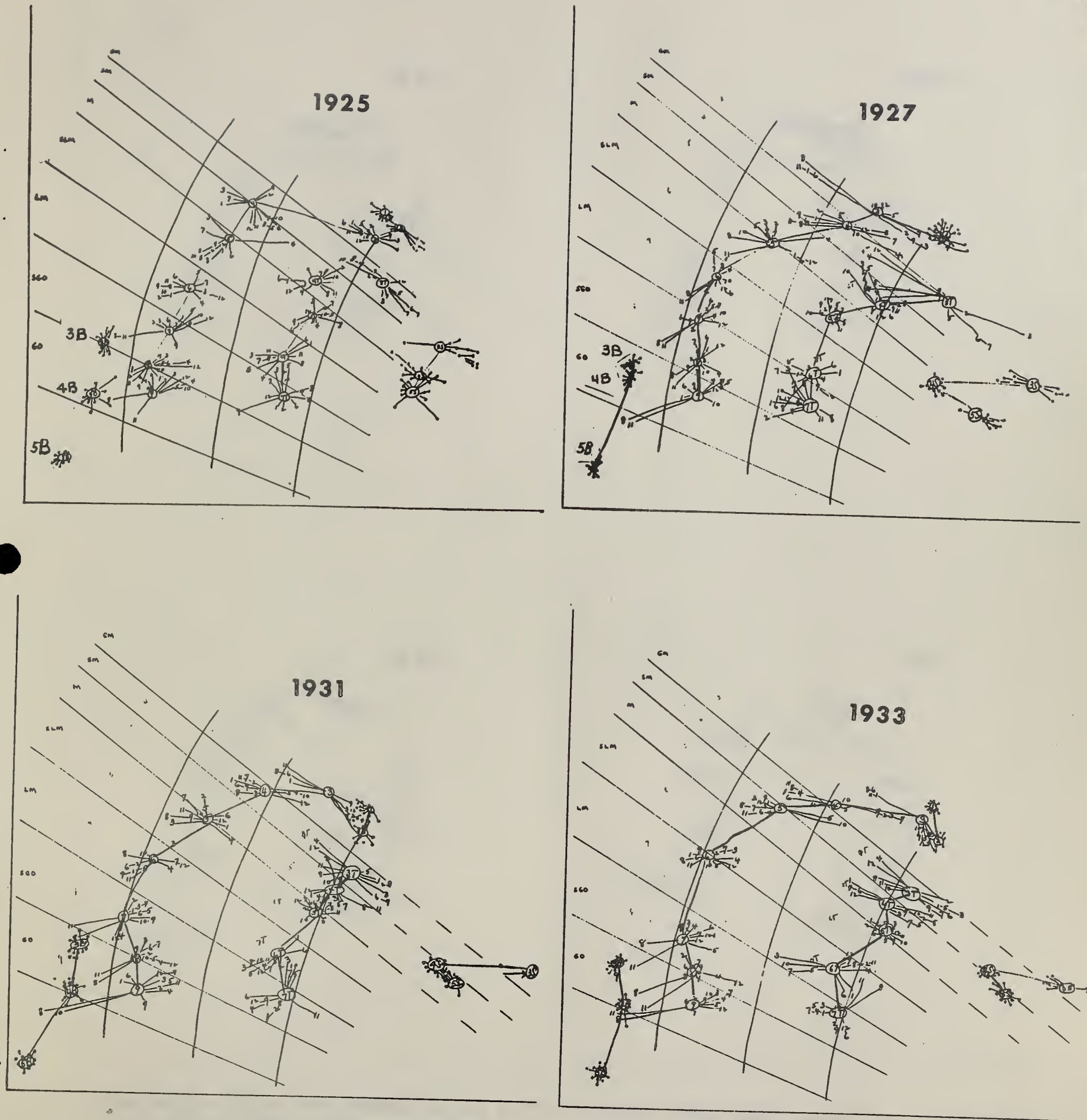


Figure 3.--Color measurements in 1954 of white and colored grade standards passed in 1925, 1927, 1931, and 1933.

Figure 4.--Color measurements in 1954 of grade standards passed at conferences of 1936, 1939, 1946, and 1950.

Only white grades from these early standards are shown in figures 1 and 2. In figures 3 and 4 the entire series of white and colored cottons are shown as they measured when taken out of the vault in 1954. Sets from 1925, 1927, 1931, and 1933 standards are shown in figure 3. These include the old Blue Stained grades, Good Middling through Middling, and a set of Tinged and Yellow Stained grades. Although the white cottons all seem considerably yellower, even in the lower grades, than cottons in today's U. S. standards and the Stained cottons are far yellower than any cottons from current crops, many of the Tinged samples, particularly in the lower grades, do not seem to carry more color than the Tinged grades of today. As in previous standards, cottons that originally graded as high or higher than Strict Middling changed most. For example, grades marked 1, 2, and 3 have changed at least as far as the Tinges, or even to the color of the present Good Middling Stained; the Good Middling Tinge follows the same pattern of change, particularly in 1925 and 1927. The old Blues follow a pattern similar to that set up today for the Gray cottons. Grays today are described with a difference of three grades between color and leaf; the Blue grades could be described as having a difference of five grades between color and leaf. For example, Good Middling Blue has the foreign matter content of Good Middling, but it is slightly lower in color than the present Strict Good Ordinary, a difference of five grades in color. Grade Strict Middling Blue has the foreign matter content of Strict Middling but the color is about that of Good Ordinary, a difference of five grades. And Middling Blue is below Good Ordinary in color, which again provides a difference of five grades.

It is interesting to note that on the basis of the diagrams in figures 1 through 4, the range of samples from high grade to low grade remains today about as it was in those early days: Good Middling is up in the range shown on the present diagram for Good Middling, and Good Ordinary is down in the range shown for Good Ordinary. There are differences in yellowness, but overall difference in level between Good Middling and Good Ordinary seems today about what it has been through all of the years of standards. On the other hand, the exact levels of the grades between Good Middling and Good Ordinary seem to have changed somewhat from time to time, with intervals in some series of standards more uniform than in others. Intervals for 1925 standards seem fairly uniform, although grades 4 through 8 are somewhat lower than at present. On the other hand, in 1925 the level of grade 4 was up, and other grades seem to have been pulled up slightly. By 1933 Middling was well up in comparison to our present Middling, but the Low Middling was still down, so that the grades 7 through 9 were not stepped as regularly as they are today.

Figure 4 shows standards from conferences of 1936, when the standards were changed, and from 1939, 1946, and 1950. Grade intervals seem to have been smoothed out considerably as time went on, and it might therefore be of interest at this point to know that the color laboratory was established in 1927, although it was not really in operation for practical standards work until the 1933 conference. In its earlier days color laboratory work on the standards was confined to measuring a given set of standards

and indicating to the classing group whether new bales were like the old. Gradually, as the laboratory gained experience and background in the cotton work, and as the standards group learned more about the practicability of the color work, grade intervals in the standards became more uniform. This seems clear if one follows the diagrams for the standards of 1936, on to 1939, to 1946, for in 1946 although the Low Middling still remained toward the low side of the present Low Middling, all of the other grades became more evenly stepped. In 1950 the cotton colorimeter was used for the first time in the classing room operation of putting up standards.

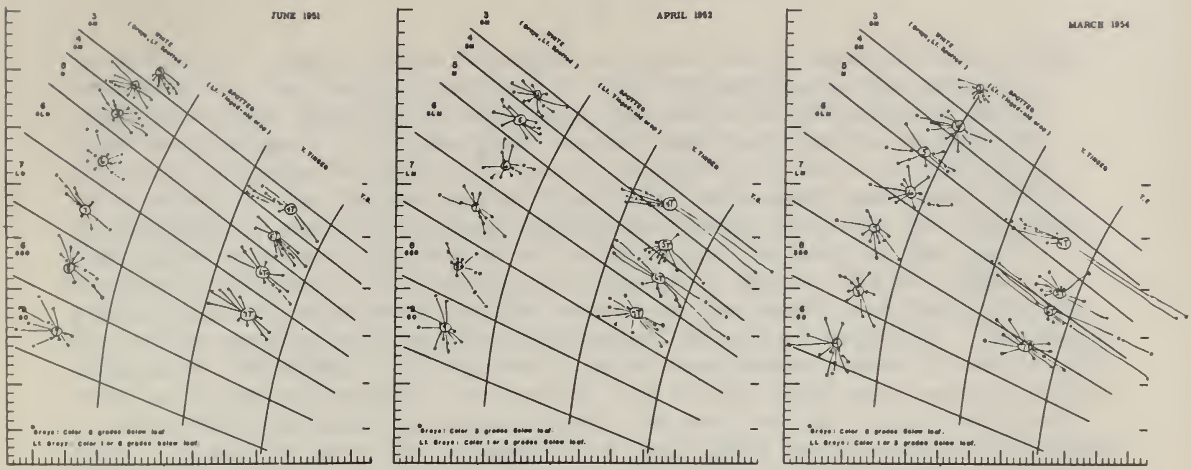
Although the measurements shown in figures 1 to 4 include any change that has taken place since the year in which the standards were put up, it is useful and very practical to know that the level of color for the various grades shows little change if samples are protected from dirt and dust. (It takes very little dust and dirt for a box of standards to measure progressively a quarter, half, and even a full grade, lower than it should. For this reason it is essential that boxes be handled with care, and that fresh boxes be opened for any final comparisons in grade standards preparation.)

Figure 5 contains perhaps the most practical information for the cotton classer today, particularly the Government classer. In this one figure we have measurements at three different times, on three sets of standards connected with the present Universal Standards for Grade of American Upland Cotton. The upper series of three diagrams refers to the 1951 proposed set, the set that was carried around the country and shown in 1951 to interested groups in many places. The middle set of diagrams refers to set No. 101, adopted as the 1952 Original standard, made from bales bought after general approval of the proposed set, and put up to duplicate the 1951 proposed set (which had been made from samples selected from extensive grade surveys by Government classing offices in 1950-51). The lower set of diagrams in figure 5 represents the 1952 standards as they were put up for the 1953 conference.

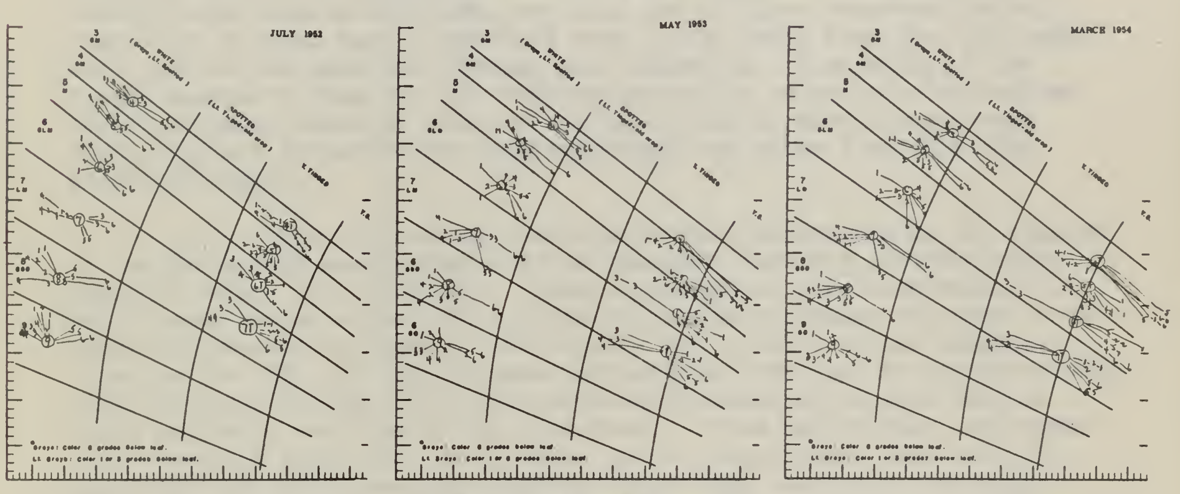
Let us examine these diagrams, set by set, starting with the 1951 proposed set. Measurements made in July 1951 show the range and the uniformity of grade steps that were based on survey samples supplied by Government classing offices. In April 1952, this same set measured as shown in the middle diagram of the top row. The main change is in a decided yellowing of a few samples in three Tinged grades. A slight yellowing of the higher grades is also evident, although by April 1952 the color was still within the blocks on which the new standards diagram is based. By March 1954, as shown in the diagram at the upper right corner of figure 5, this set of samples had taken an awful beating. This is shown by a general lowering of color in each grade because of considerable use and exposure and a yellowing, particularly in the high grades, because of time. The Tinged bales that changed by April 1952, changed even more by March 1954. Note, however, that many Tinged bales have not yet changed to any considerable degree.

Second, let us examine the 1952 Original Standard, the bales for which were purchased to fit into a color diagram based on the 1951 proposed set. By the time of the 1952 standards conference it was decided that bales

1951 PROPOSED SET - SHOWN TO COTTON TRADE, U. S. AND LE HAVRE - JUNE TO NOVEMBER 1951



1952 ORIGINAL - #101 - ADOPTED AT LE HAVRE JULY 1952 (NOW IN VAULT)



1953 STANDARDS - AS PUT UP FOR 1953 CONFERENCE

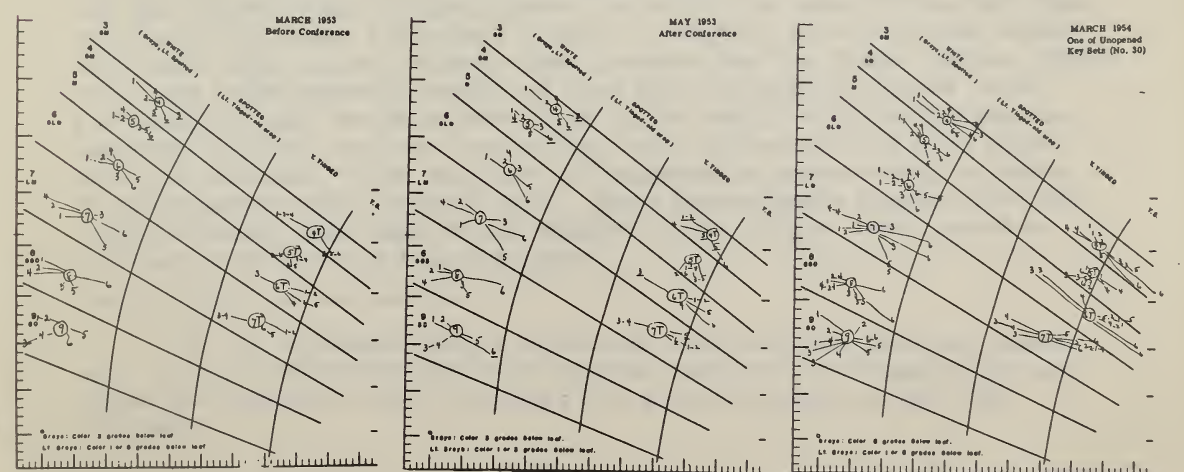


Figure 5.--Color story of current cotton grade standards: Original and recent measurements of 1951 proposed set; of 1952 Original set adopted at Le Havre July 1952; of 1953 standards put up for the 1953 conference.

in positions 1 and 2 in the 6-sample box would be obtained from the South Central area, the bale in position 3 from the Southeast, the bale in position 4 from the Western territory, and bales in positions 5 and 6 from the Southwest. Bale position numbers are included in diagrams of this and following standards 6/ to accord with this decision. Measurements shown in the diagram marked "May 1953" were made immediately after the conference when the Original Standards became available for the first time after they had been sealed at Le Havre and put away in the vault. The middle diagram of the second row (figure 5) shows that the high grades yellowed considerably while stored in the vault, and that many of the Tinged samples yellowed more than might have been expected. The third diagram of the middle row (figure 5) shows measurements made in March 1954 when the Original Standard was brought out of the vault and measured again in order that it might be compared with the rest of the series reported here. As may be seen, the tendency for the higher grade samples to yellow continued. Samples in the two lowest grades have not yellowed very much, although there is a slight difference in level between the original measurements and those of May 1954, owing to use of these standards and accumulation of such dust as gathered even in the brief time that the boxes were open on the table for viewing and comparison. A majority of the Tinged samples in this box are now deep enough in color to be classed as Yellow Stained, although a few of the bales seem to have changed very little (bale 3 in Strict Low Middling Tinged and bales 3 and 4 in Low Middling Tinged).

As for the third series, the bale numbers underlined in the diagram of the March 1953 measurements of the standards for 1953 indicate bales replaced before the conference. These replacements were made because it had already become evident that bales originally purchased for these positions had changed too much to allow their use if the original diagram, based on the 1951 and 1952 proposed and adopted sets, was to be maintained. Directly after the May 1953 conference measurements again were made on boxes put up at the time of the conference. These measurements indicated that evidently the selection of color in the Tinged boxes that were prepared for the conference was slightly better than the later selection, even though samples in the boxes measured after the conference were from the same bales. This slightly poorer selection is shown by the fact that for "May 1953, After Conference" there is slightly more extension beyond the Tinges into colors yellower than intended for the Tinged grades. Note, too, that replacements already had been made for several Tinged bales. For example, only two bales were used in the Strict Middling Tinged box measured in March, but the week before the conference three more bales were put into use. Note now what had happened to these boxes, as shown by measurements made in March 1954. These measurements support the clear visual evidence that many of the samples in the Tinged boxes passed at the conference are now Yellow Stained.

6/ In 12-sample boxes, duplicates from the same bale are placed side by side, therefore the bale position numbers of a 6-sample box are given and repeated in the 12-sample box finally adopted as the 1952 original.

With this story and with this set of diagrams--particularly figure 5 which shows measurements on the present standards--it should be clear why boxes of standards purchased at different times may not always look alike in color. Specifications for the purchase of bales for the standards remain the same, whether the bales were purchased in 1951 for the original set, or in 1953 for preparing copies for 1954 distribution. These specifications should help to keep the color, leaf, and preparation as they were set up originally for the present standards. This means that some of the boxes may look very different as put up for a new season when they replace boxes that have changed to such a degree that they are clearly different. With reference to cottons in the present standards that may have changed, it should be remembered that most of the cottons in the original boxes were purchased from the 1951 crop and were assembled in the spring of 1952; an Original was adopted in the summer of 1952 and duplicate boxes (made in large part from cotton from the same bales) were passed by the Universal Cotton Grade Standards Conference in May 1953. Consequently, many of these cottons are now (1954) more than 3 years old.

At the present time measurements are made of a random selection of shipments of standards. These measurements are made for two purposes, one to keep a check on the bales in use, and second, to see that when shipped the color is about where it should be on the color diagram. All of the samples are measured when they are put up, but if old bales are used to replace bales that become exhausted, there may have been time for change between the original preparation of the old bale and its shipment as a part of the standards. Therefore, a final check is necessary.

Figure 6 shows a set of white standards in which there is a considerable amount of cotton purchased from the 1953 crop. For the most part these are similar to white standards that have been shipped, or will be, during the coming season. Although some of them may not be back in color exactly where we want them for all of the individual samples, they do show the proper level and a good spread within each grade. As for Tinges, the range shown in figure 6 for Tinges represents our present stock of bales for standards use, excluding those that have yellowed so much that they are now Yellow Stained. As they can be found, other bales will be purchased to provide complete coverage of each grade. It is hoped that the more recent purchases will stay put longer than the bales in the 1953 standards. Already sources for Tinged bales are being studied to see whether it is possible to find and use bales that will not change as rapidly as the 1952-53 standards bales have done. Measurements of the old Tinged cottons (figures 3 and 4) show many of these cottons still well within the present Tinges, and it seems as if it should be possible to find a satisfactory answer to this problem. If not, it may be necessary to make boxes valid for color for 1 year only. Meanwhile, if the color of one box does not always match the color of another, classers will know why.

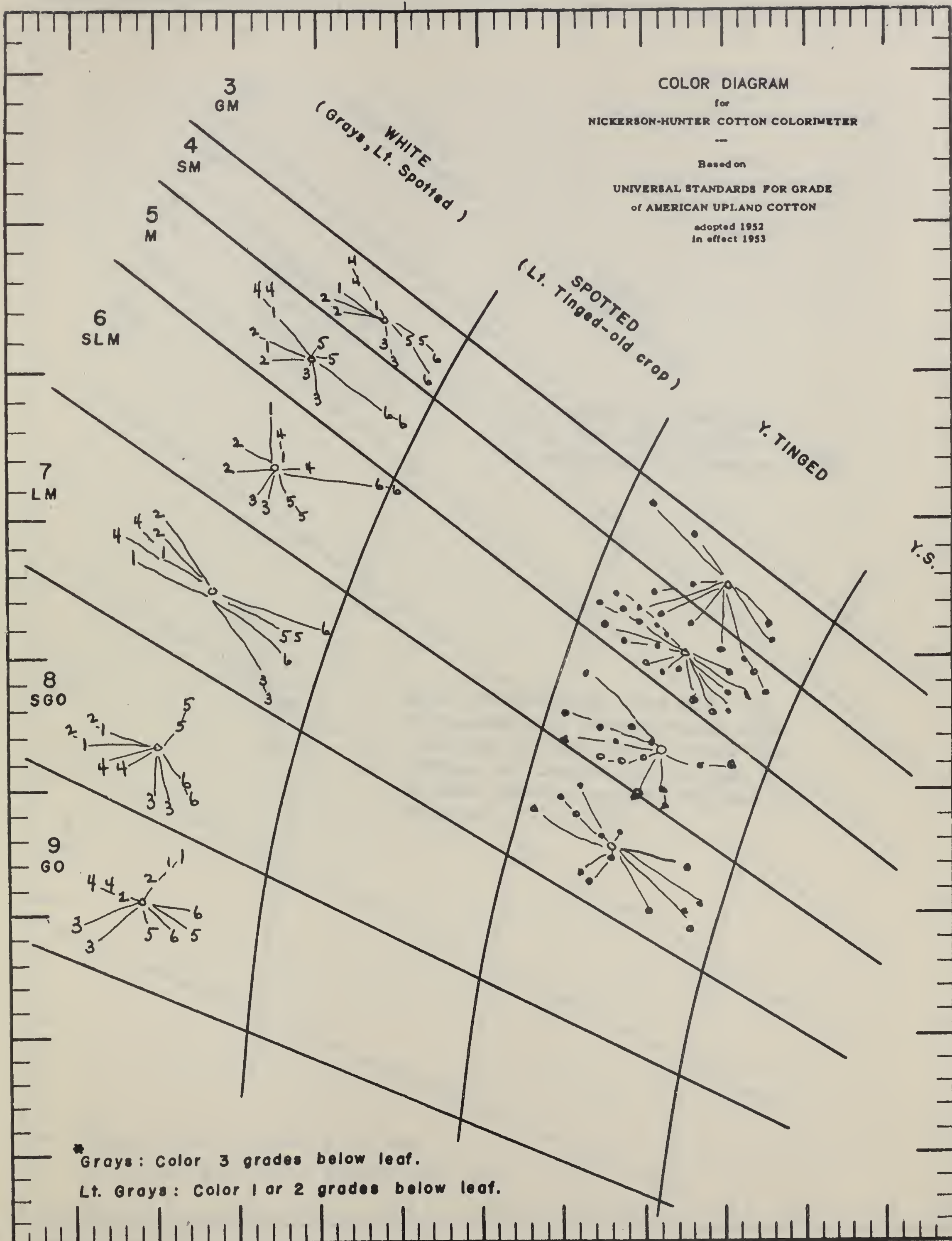


Figure 6.--A set of white standards made from bales in stock 1954; range of Tinged bales available for standards use 1954.

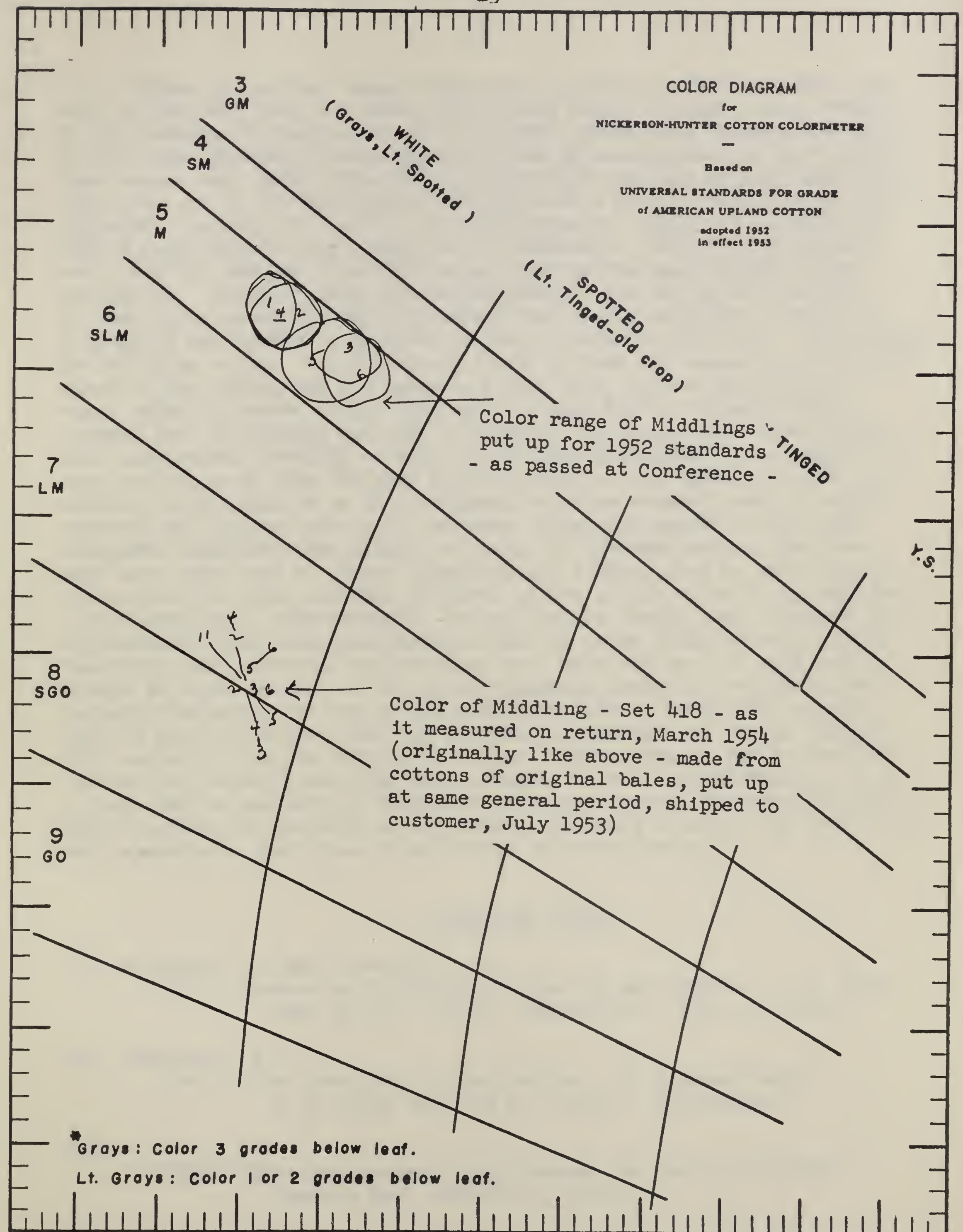


Figure 7.--To illustrate extent of possible change due to use: Color measurements of samples used in Middling boxes put up for 1953 conference, and one box measured on its return after July to March use.

There is another change that may be clearly visible, one that may seem to indicate that new boxes look better than old boxes. This, however, it not because the new box is on a different level, but because the color of old boxes gradually deteriorates in use by accumulation of dust layers that cannot help being deposited on boxes that are used in any busy classing room. If in the Washington classing room a box is found to have deteriorated a quarter of a grade, or possibly half a grade, it is replaced with a fresh set for any comparison of standards. Figure 7 illustrates how low a box can get from this cause, without the cause always being recognized. Figure 7 shows the measurement of a Middling box returned to Washington recently with the request that it be replaced. Never had a Middling box looked or measured as low in color as this one! It measured Low Middling color. The surprising thing is that the cause was not recognized by the cotton man who owned and used this box; he compared it to boxes owned by others in his town and, because his box looked lower, assumed that Washington had made a mistake. But this is the sort of mistake that cannot possibly be made in putting up standards, for samples in each box are made from the same bales as long as the bales last. The bale numbers on the samples in this returned box were checked, and it turned out that the box was put up of the same cotton and passed by the same standards committee that passed on boxes for the conference. This box must have been used or opened enough to get a heavy dust or smoke layer on it, for its color actually measured as low as the color in a fresh box of Low Middling. Unfortunately, if the leaf is right, many classers tend to overlook color deterioration even when it is as large as this one was. Therefore, the practical classing man must keep the fact of this sort of change in mind, as well as the facts regarding change by yellowing that he more frequently notices as his bales get older. Otherwise, he will find it easy to believe that any new set of standards is better than his old used set. The new set may be better, but the reason may be that the old set has deteriorated from use. Because of this deterioration, it is a good idea to use sets of standards in pairs, one set for every day use, and the other for use only as a reference standard to which the first set may be compared when there is any doubt of its validity.

LITERATURE CITED

(1) Nickerson, D. and Milstead, L. D.
1933. Studies of Stability of Color in Raw Cotton. U. S. Dept. Agr. 22 pp., illus. (Processed.) (Out of print.)

(2) Nickerson, D.
1941. Color Stability in Raw Cotton. II. Storage Tests. U. S. Dept. Agr. 16 pp., illus. (Processed.)

(3) ________
1946. Color Measurements of Standards for Grades of Cotton. Textile Res. 16:441-449, illus.

(4) Nickerson, D.
1950. Color Measurements of Cotton. Preliminary report on application of new automatic cotton colorimeter. Cotton Br., Prod. Mktg. Admin., U. S. Dept. Agr. 18 pp., illus. (Processed.)

(5) ______
1951. Effect of Exposure and Storage on Color and Other Factors of Quality in Raw Cotton. Cotton Br., Prod. Mktg. Admin., U. S. Dept. Agr. 38 pp., illus. (Processed.)

(6) ______
1953. Color Measurements of Cotton. Second report on application of Nickerson-Hunter Cotton Colorimeter, Including a discussion of recent work on standards for grade. Cotton Br., Prod. Mktg. Admin., U. S. Dept. Agr. 38 pp., illus. (Processed.)

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

~~COTTON~~ COLOR MEASUREMENT DATA RELATING TO GRADE STANDARDS FOR COTTON AND COTTON LINTERS

Washington, D. C.
May 1956

For Administrative Use

For Administrative Use May 1956

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

COLOR MEASUREMENT DATA RELATING TO GRADE STANDARDS FOR COTTON AND COTTON LINTERS

By Dorothy Nickerson, Cotton Division

This report consists of a series of diagrams and tables that provide background information and illustrate the progress of grade standards work from 1950 to 1956 through color measurements which have been obtained by use of the Nickerson-Hunter Cotton Colorimeter. The titles of the diagrams are designed to tell the story, and the sequence to provide background information for what follows. The diagrams and tables are grouped as shown.

Figures 1 - 7	General background information.
Figures 8 - 16	Original standards and bales, 1952-1956.
Figures 17 - 22	Copies of standards, random sets as issued between conferences, including replacement bales.
Tables 1 - 2	Usual amount of cotton put up from each bale, and number of boxes and samples distributed 1953-1955. (Basis for estimating requirements.)
Figures 23 - 26	With figures 8 to 16, these diagrams provide information on color change of cottons held in Washington and elsewhere for Spotted, White, and Tinged.
Figures 27 - 31	Change of standards in use. Measurements on sets returned after use.
Figures 32 - 34 Tables 3 - 4	Trash (nonlint) data for standards and crop.
Figure 35	Color of lint cotton, after removal of trash (nonlint) content.
Figures 36 - 38	Range of color in standards for 1956 conference.
Figures 39 - 41	Color of American Egyptian — standards and crop.
Figures 42 - 44	Color of Cotton Linters — standards and crop.

Contents

Figure 19.--Random sets before photographing, August 1954.

Figure 20.--Random sets before photographing, February 1955.

Figure 21.--Random sets before photographing, April 1955.

Figure 22.--Random sets before photographing, September 1955.

Table 1.--Number of samples put up out of typical 1956 standards bales.

Table 2.--Number of large and small boxes of each grade shipped for three years, 1953-1955, with total number of samples required for each bale position.

Figure 23.--Average color change in storage for Original standards and guides, White, Spotted, and Tinged.

Figure 24.--Color change of White grade standards in storage indicated in units of color difference, ΔE, by number of months held in Washington.

Figure 25.--Color change, ΔE, by months of storage, indicated for each bale in White, Spotted, and Tinged grades held in Washington under classing room conditions, and under refrigeration at about 38°.

Figure 26.--Color change, ΔE, by months of storage, in sets of Spotted Guide boxes stored in several locations since 1953 grade standards conference.

Figure 27.--Colorimeter and classer comparisons on a typical set of White standards returned after use.

Figure 28.--Measurement on sets of standards typical of those returned after use.

Figure 29.--Measurements on standards returned after use in one office in one season.

Figure 30.--Measurements on returned standards, after use of 18 months or less.

Figure 31.--Colorimetric comparisons on typical sets of Light Spotted boxes returned after use.

Figure 32.--Trash analysis for bales used in standards, 1936-1956.

Figure 33.--Trash (nonlint) content of cottons classed in White grades: U. S. cotton crops, 1951-1953.

Tables 1 and 2 follow figure 22.

Tables 3 and 4 follow figure 34.

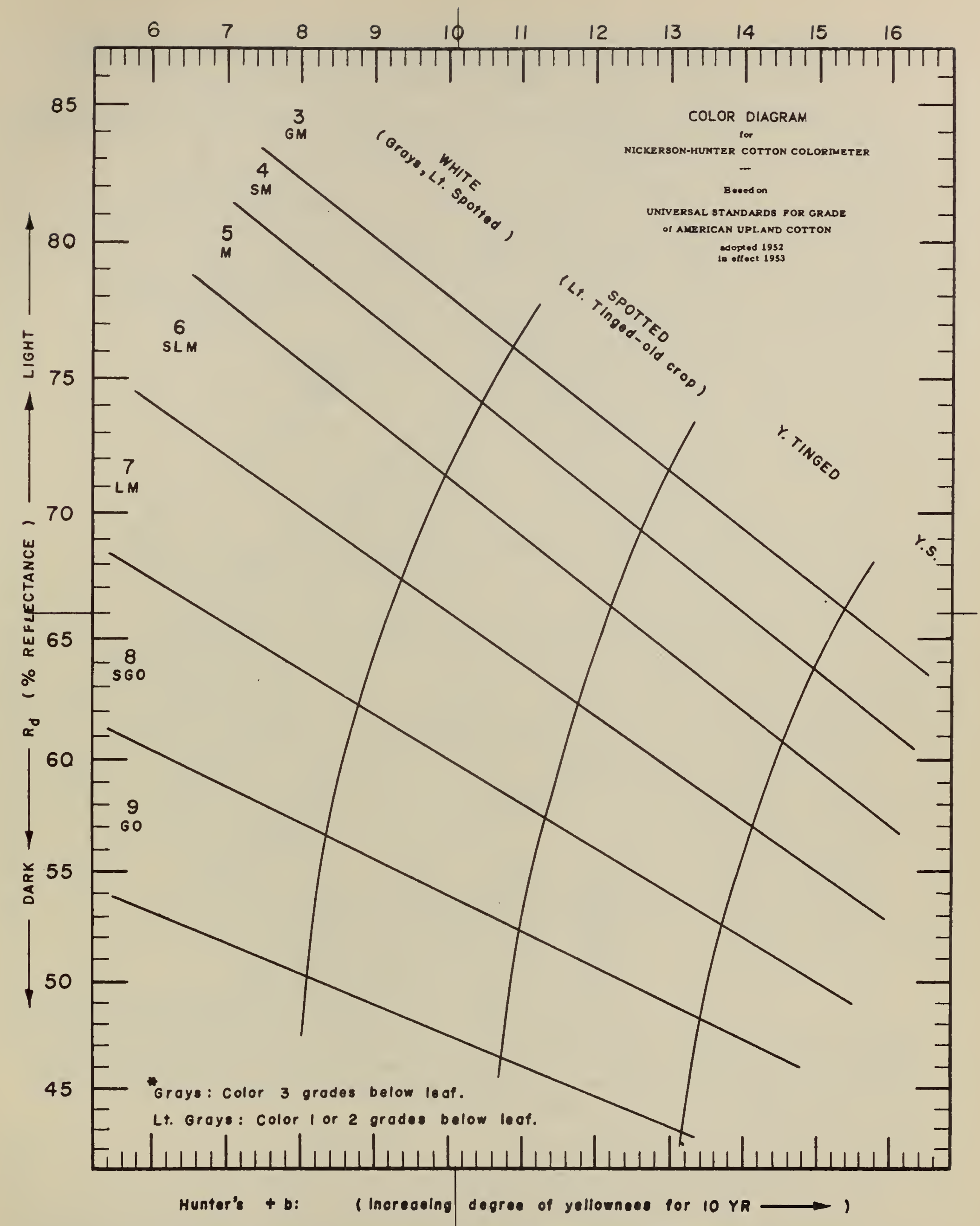
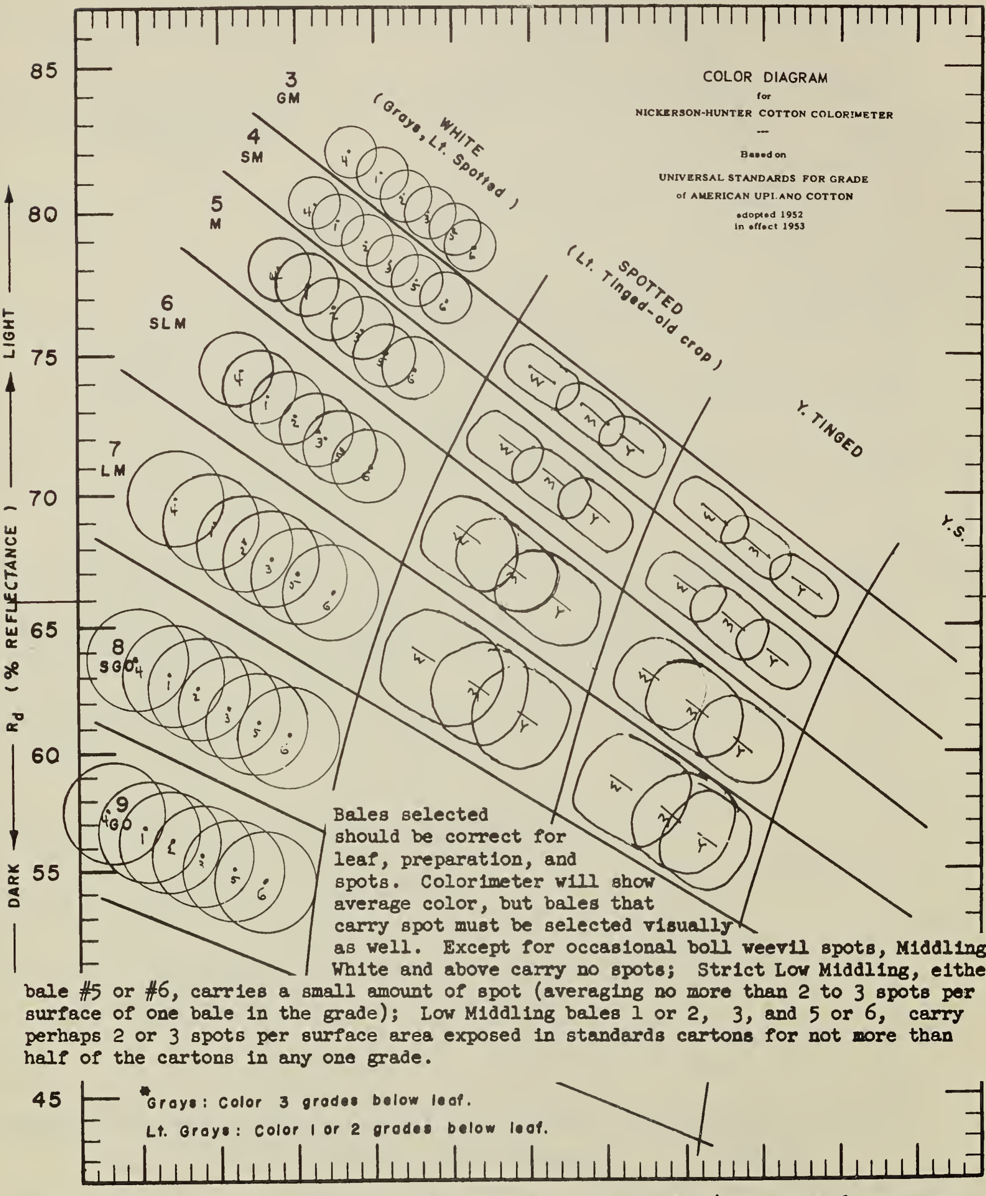


FIGURE 1.--COLOR DIAGRAM OF COTTON GRADES FOR THE NICKERSON-HUNTER COTTON COLORIMETER.

Color has three dimensions (hue, lightness, and chroma) but hue is so nearly constant for cotton that measurements of lightness and chroma are sufficient to define the color of cotton grades. Hunter scales used in this instrument are indicated in a vertical direction by percent reflectance (R_d), which measures the lightness of a sample, and in a horizontal direction by Hunter's +b which, for this instrument, indicates the degree of yellowness (with hue constant) and thus provides a measure of chroma. High grades are toward the top of the diagram, low grades toward the bottom; gray colors are toward the left, and tinged or stained colors toward the right The original of this diagram fits over the diagram on the instrument, so that indicated points may be plotted directly.

Guides for purchase of bales for standards. Dots (white grades) and short lines (spots and tinges) represent color positions wanted. Circles and ellipses indicate range of samples expected within purchased bales.

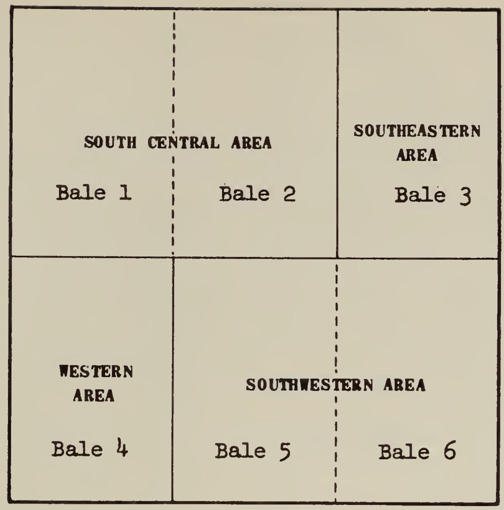


Bales selected should be correct for leaf, preparation, and spots. Colorimeter will show average color, but bales that carry spot must be selected visually as well. Except for occasional boll weevil spots, Middling White and above carry no spots; Strict Low Middling, either bale #5 or #6, carries a small amount of spot (averaging no more than 2 to 3 spots per surface of one bale in the grade); Low Middling bales 1 or 2, 3, and 5 or 6, carry perhaps 2 or 3 spots per surface area exposed in standards cartons for not more than half of the cartons in any one grade.

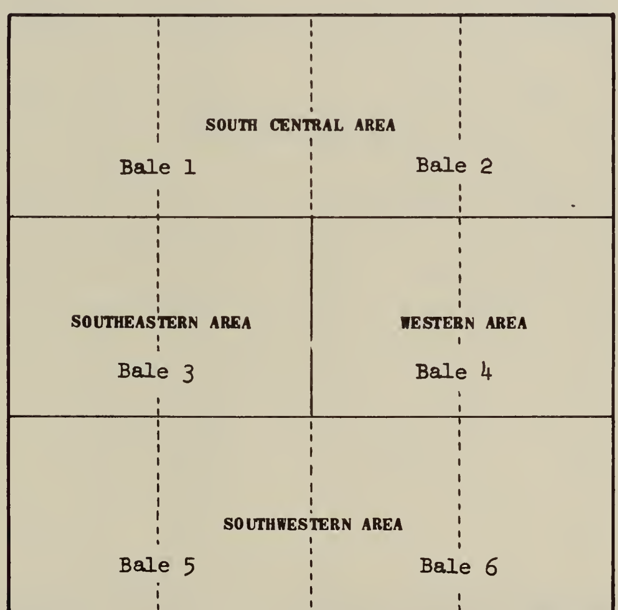
Bale positions 1,2 represent S.Central cottons; 3, Southeast; 4, West; 5,6,Southwest. For Spots and Tinges three colors W(hite), M(edium); and Y(ellow) are required.

FIGURE 2.--COLOR GUIDE FOR PURCHASE OF BALES FOR COTTON GRADE STANDARDS.

This guide is based on standards adopted in 1953 that were, in turn, based on crop survey data available for many years. Color for positions in White grades is based on the relation of the average grade color for cottons grown and classed in four cotton areas over a period of many years.



GUIDE BOXES FOR GRADE OF AMERICAN UPLAND COTTON



UNIVERSAL STANDARDS FOR AMERICAN UPLAND COTTON

FIGURE 3.--LOCATION OF SAMPLES FOR WHITE GRADES IN 6 AND 12 SAMPLE OFFICIAL BOXES BY AREA OF GROWTH.

Six bales are used. The bale numbers indicate the position in the 6-sample guide box; large boxes contain the same bales, but two samples of each.

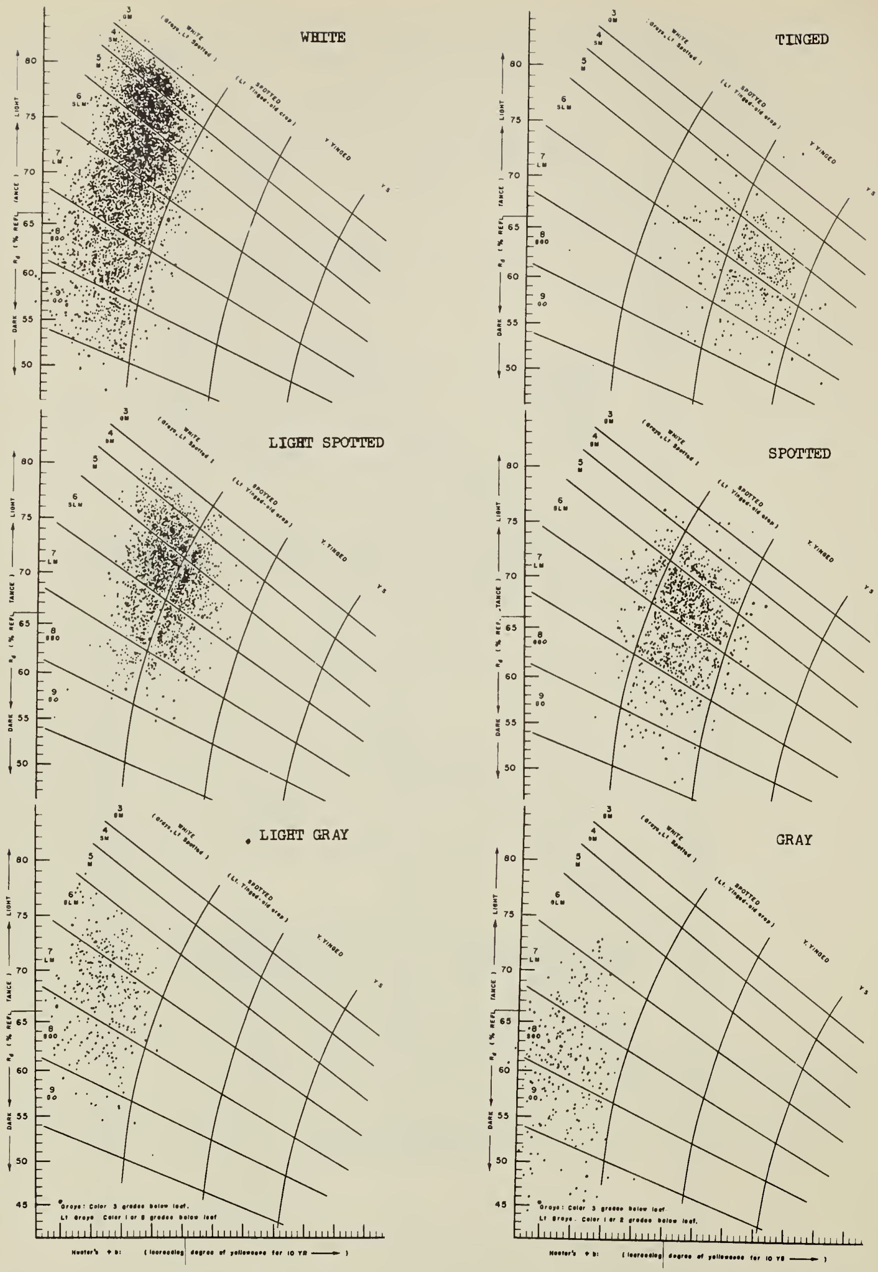


FIGURE 4.--CROP DATA FOR 1955. This is typical of information available for many past years. Each dot represents a sample classed in the color group indicated: White, Tinged (for both of which there are standards in physical form), Light Spotted, Spotted, Light Gray, Gray. The color diagram is based on the grade standards for White and Tinged cottons in use since 1953.

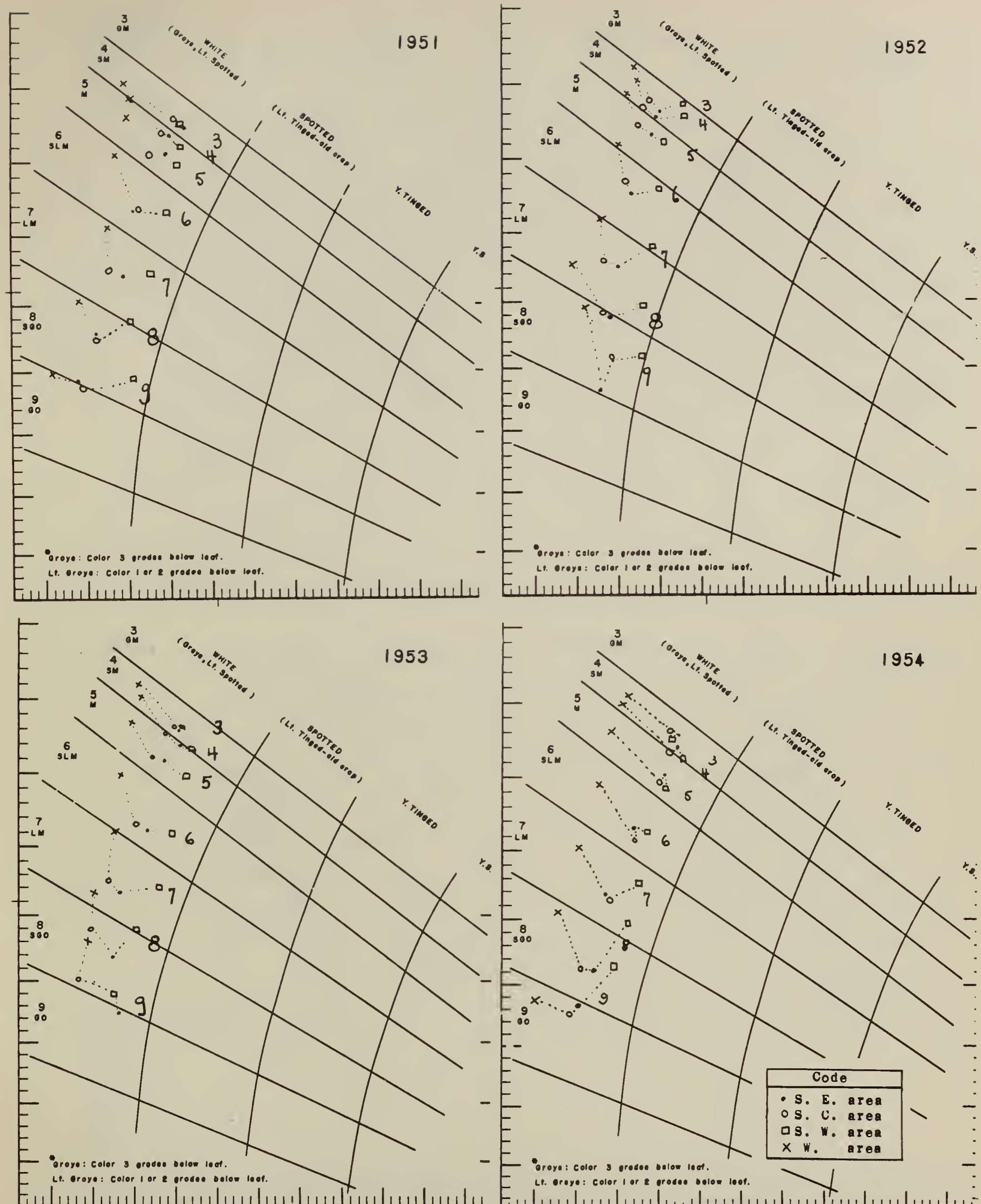


FIGURE 5.--AVERAGE COLOR OF WHITE GRADES OF COTTON AS THEY HAVE BEEN CLASSED IN FOUR AREAS FOR TYPICAL CROP YEARS, 1951 THROUGH 1954.

As shown, the Western Area cotton is the whitest or grayest in each grade, and the Southwestern Area cotton is the creamiest or yellowest.

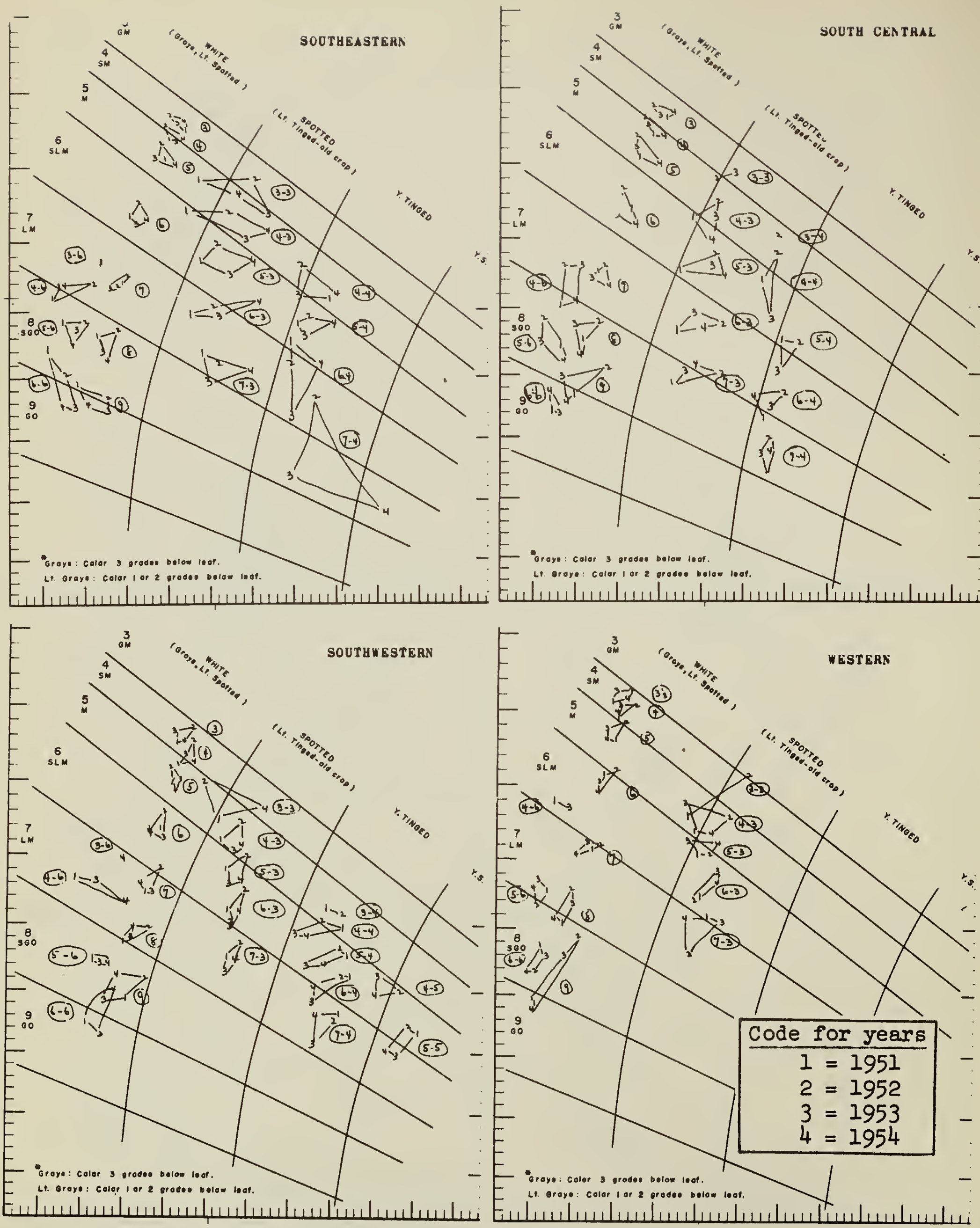


FIGURE 6.--AVERAGE COLOR OF COTTONS CLASSED IN PLUS GRADES, SPOTTED, TINGED, AND GRAYS, BY AREAS FOR FOUR CROP YEARS, 1951-1954.

Circled numbers represent the usual code for grades: 3 to 9 = M to GO. This is combined with numbers 3 for Spotted, 4 for Tinged, 5 for Stained, 6 for Gray, 9 for Light Spotted, and 8 for Light Gray. E.g., 5 is M, 5-3 is M Sp., 5-5 M St., 5-6 M Gray, 5-9 M Lt. Sp., and 5-8 M Lt.Gray.

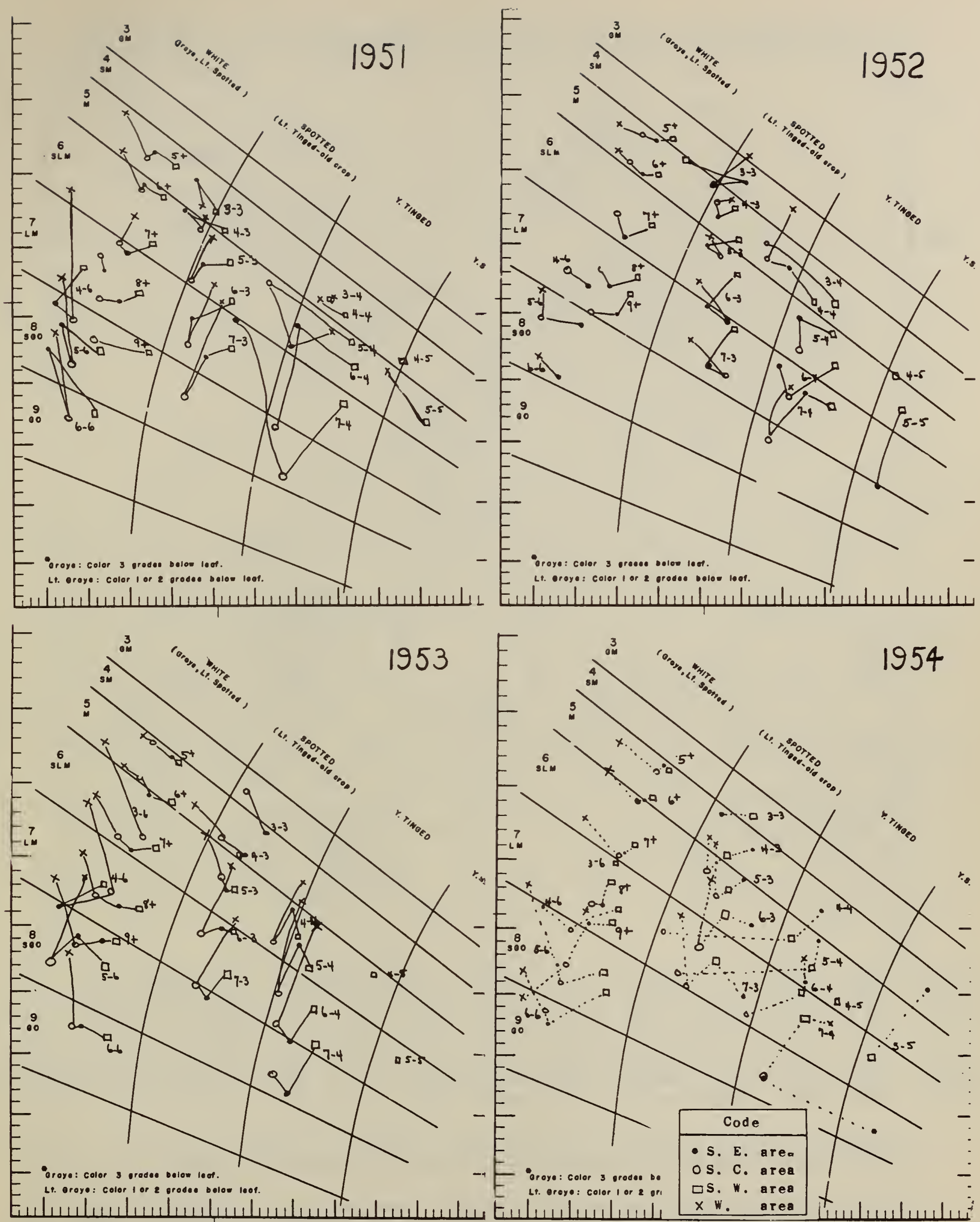
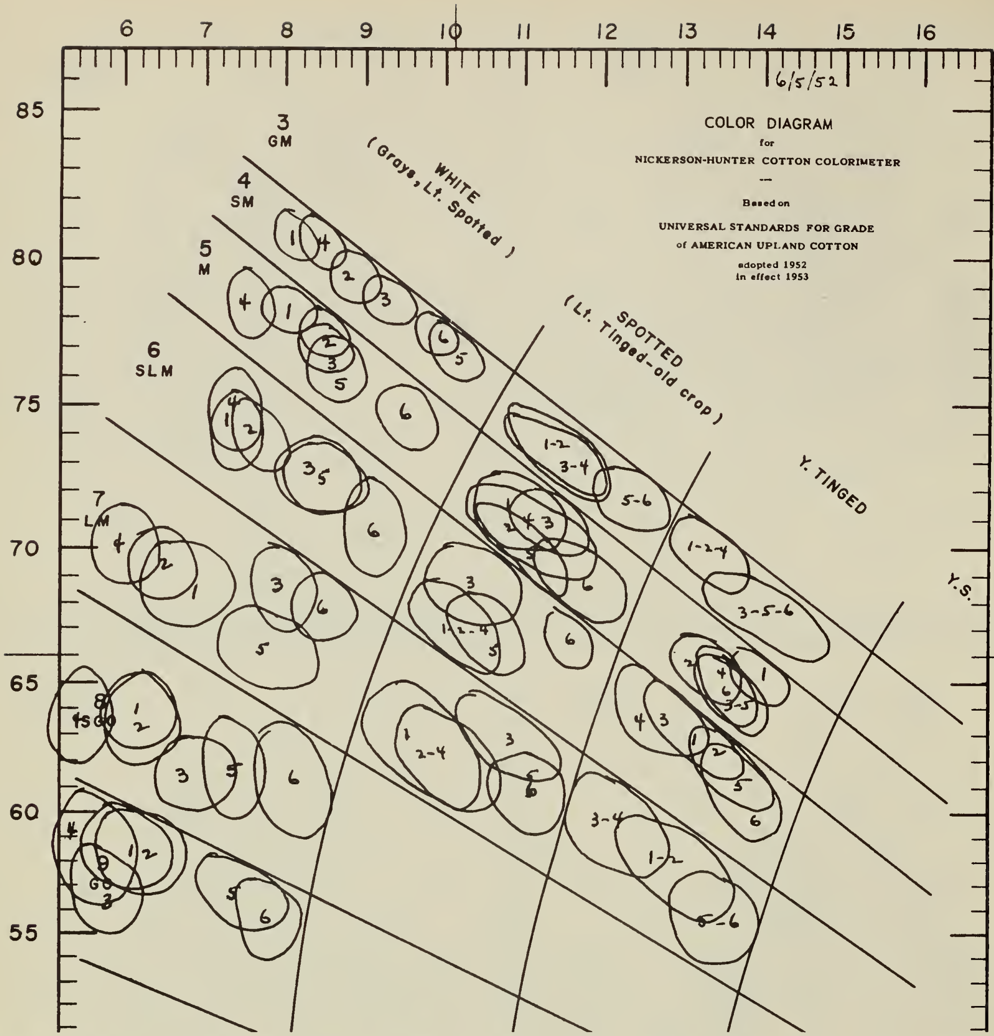


FIGURE 7.--AVERAGE COLOR OF COTTONS CLASSED IN FOUR AREAS FOR YEARS 1951-1954.
Data are for plus grades, Spotted, Tinged, and Grays.



	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	129245	876309	68328	136293	136004	695464	367656	753450	250517	32374	380046	2639716	13427	11667
2	146897	149430	1084395	879593	136005	695564	367565	499916	250517	2771	380046	13173	13427	11667
3	15294	17534	8449922	825	372322	1350315	677816	677808	179735	759793	713627	13155	17417	18218
4	588016	564143	405229	1667914	7797614	608667	677816	751034	250517	2771	380046	2597143	24078	18218
5	266981	178953	2644949	22838	2446522	13121	542617	261428	10891	28941	713627	13155	269415	11824
6	110856	266843	31601	2629166	13115	13155	542617	2657539	24078	11642	713627	13173	13369	11824

FIGURE 8.--BALES PURCHASED ON BASIS OF FIGURE 2 THAT WERE USED IN PREPARING GRADE STANDARDS ADOPTED IN 1952.

The Original Set, #101, was selected from boxes put up from these bales.

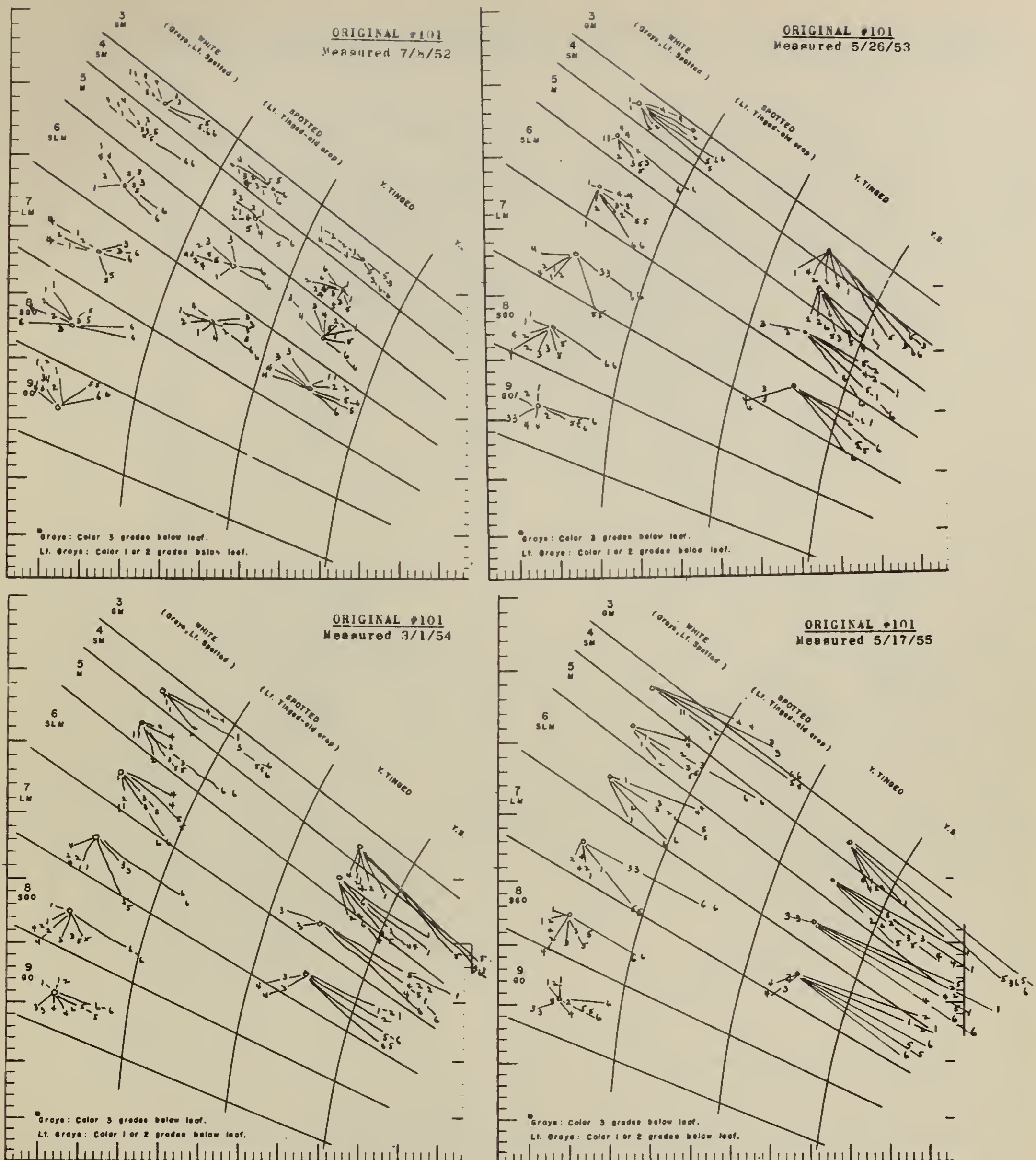


FIGURE 9.--ORIGINAL STANDARD, SET #101, FOR WHITE AND TINGED GRADES AS MEASURED AT TIME OF ADOPTION IN 1952, AND EACH YEAR FOLLOWING, 1953, 1954, 1955. (For 1956 see next figure.)

Each year the color change increased until in 1956 some or all samples in every grade except Good Ordinary have yellowed so much that they no longer are in the correct category. The small numbers indicate the bale positions.

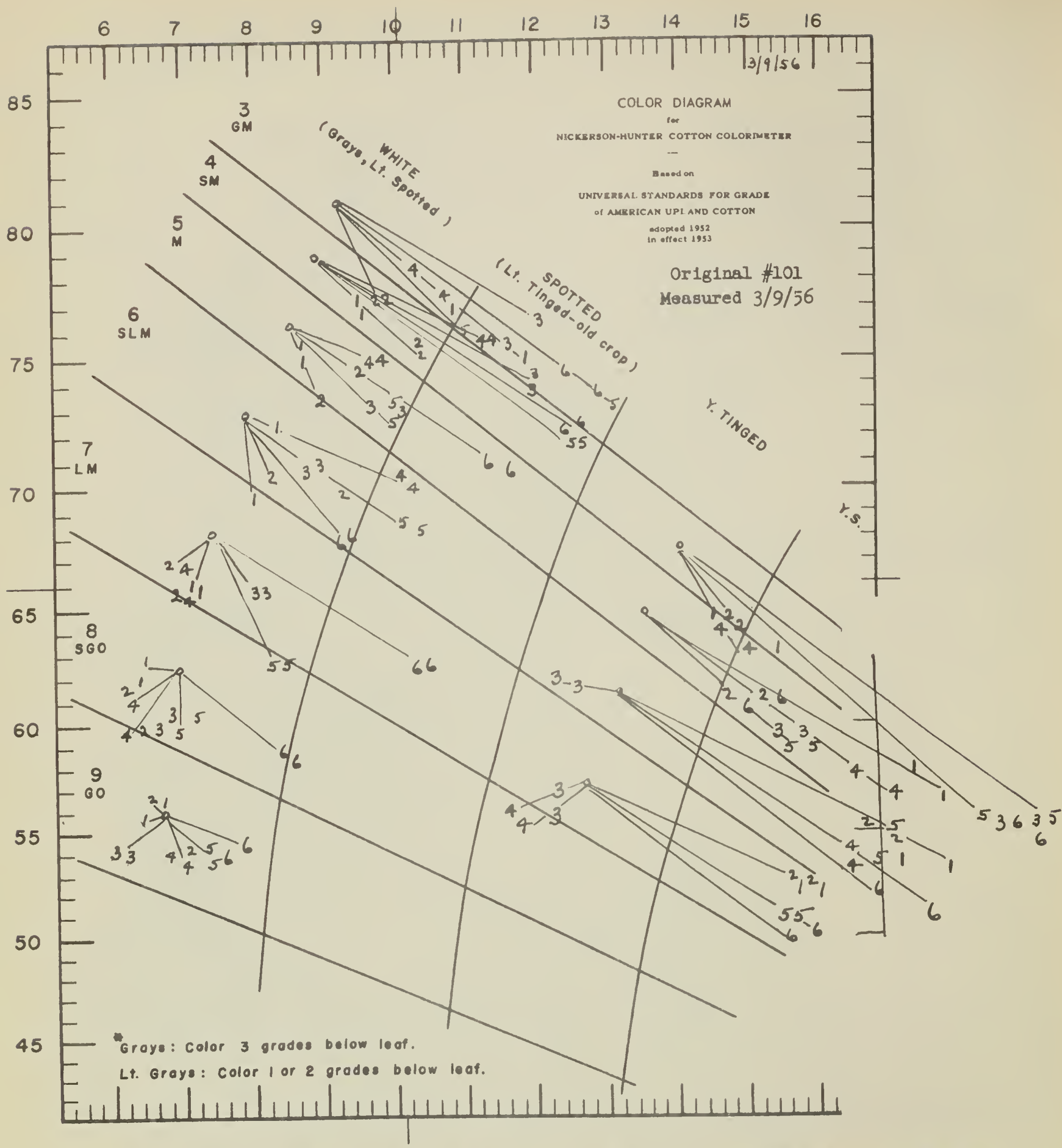


FIGURE 10.--ORIGINAL SET #101 OF WHITE AND TINGED STANDARDS AS THEY WERE MEASURED MARCH 1956, ABOUT 3-1/2 YEARS AFTER THE ORIGINAL MEASUREMENT OF JULY 1952.

The Good Middling Original was adopted 1953, effective 1954; it also shows great change.

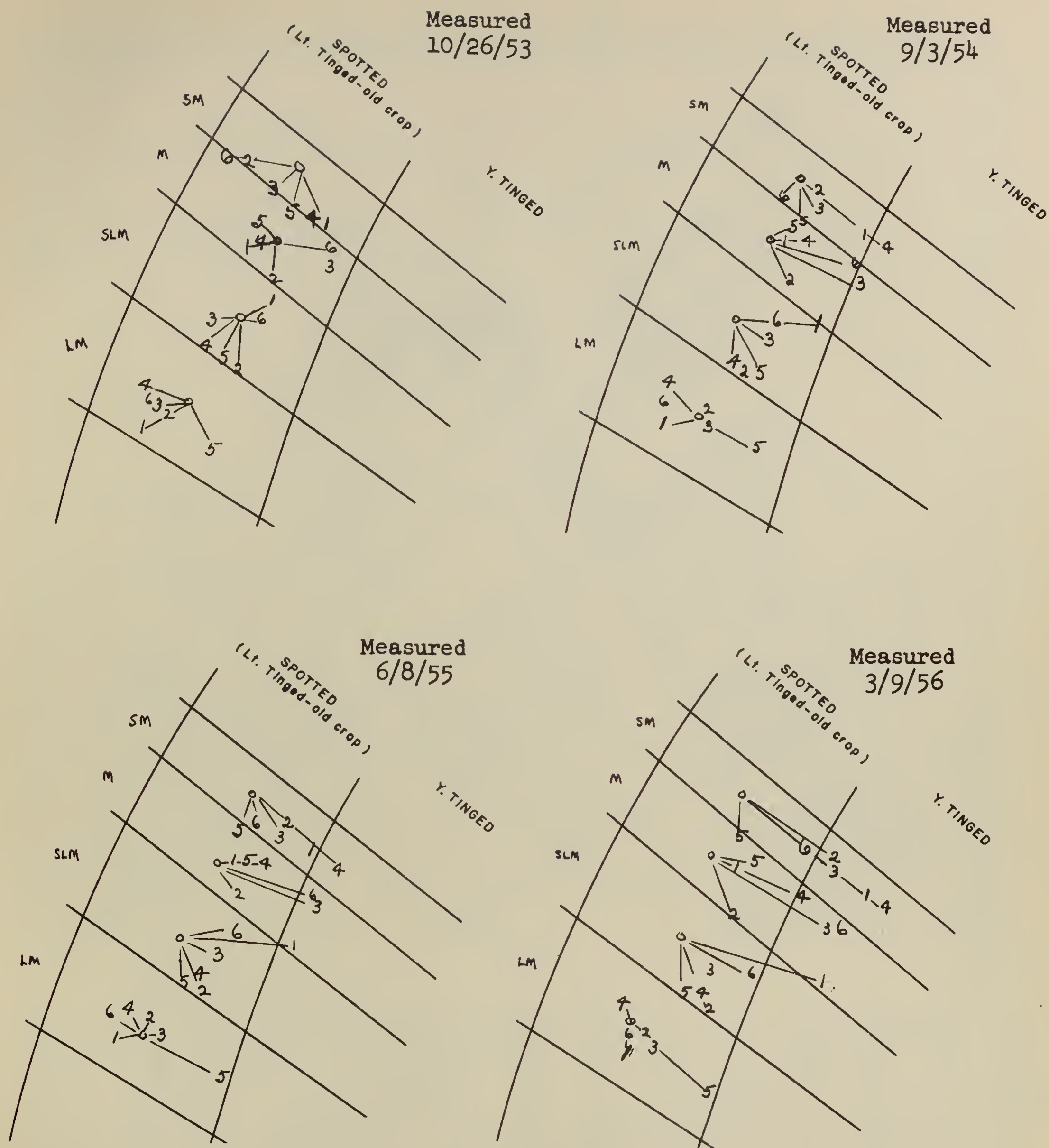


FIGURE 11.--COLOR MEASUREMENTS OF SPOTTED GUIDE, SET #00225, PUT ASIDE AS A RESERVE SET, AS MEASURED PERIODICALLY SINCE 1953.

Measurements are as made at the time Spotted Guides first were shipped, then each year later, at intervals of 11, 20, and 29 months. While these Spotted Guides show less change than sets of 1953 White and Tinged standards, this is not necessarily typical, for on the basis of other measurements it is expected that the pattern of change in Spotted cottons should fit in with the pattern of change for the White and Tinged cottons.

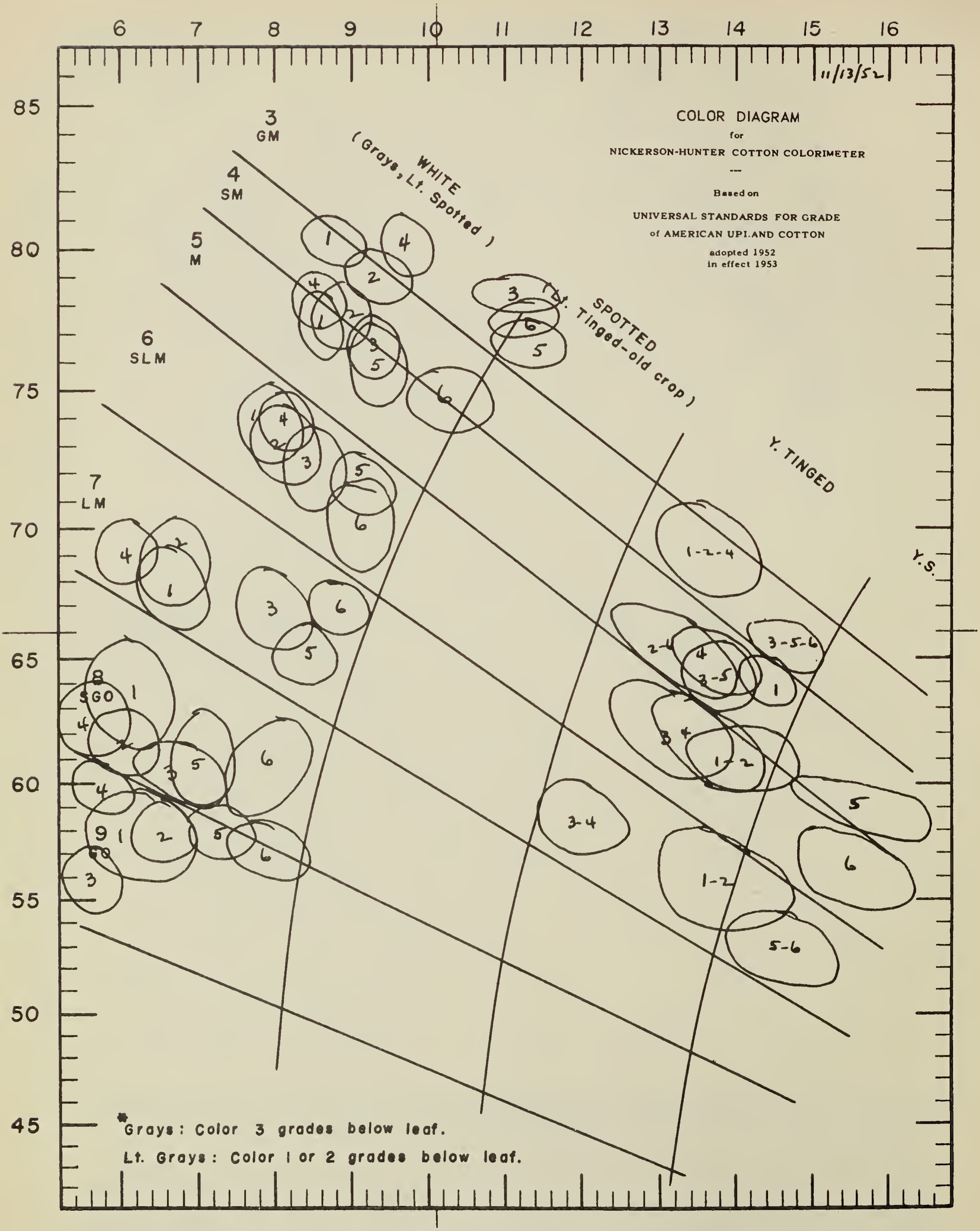
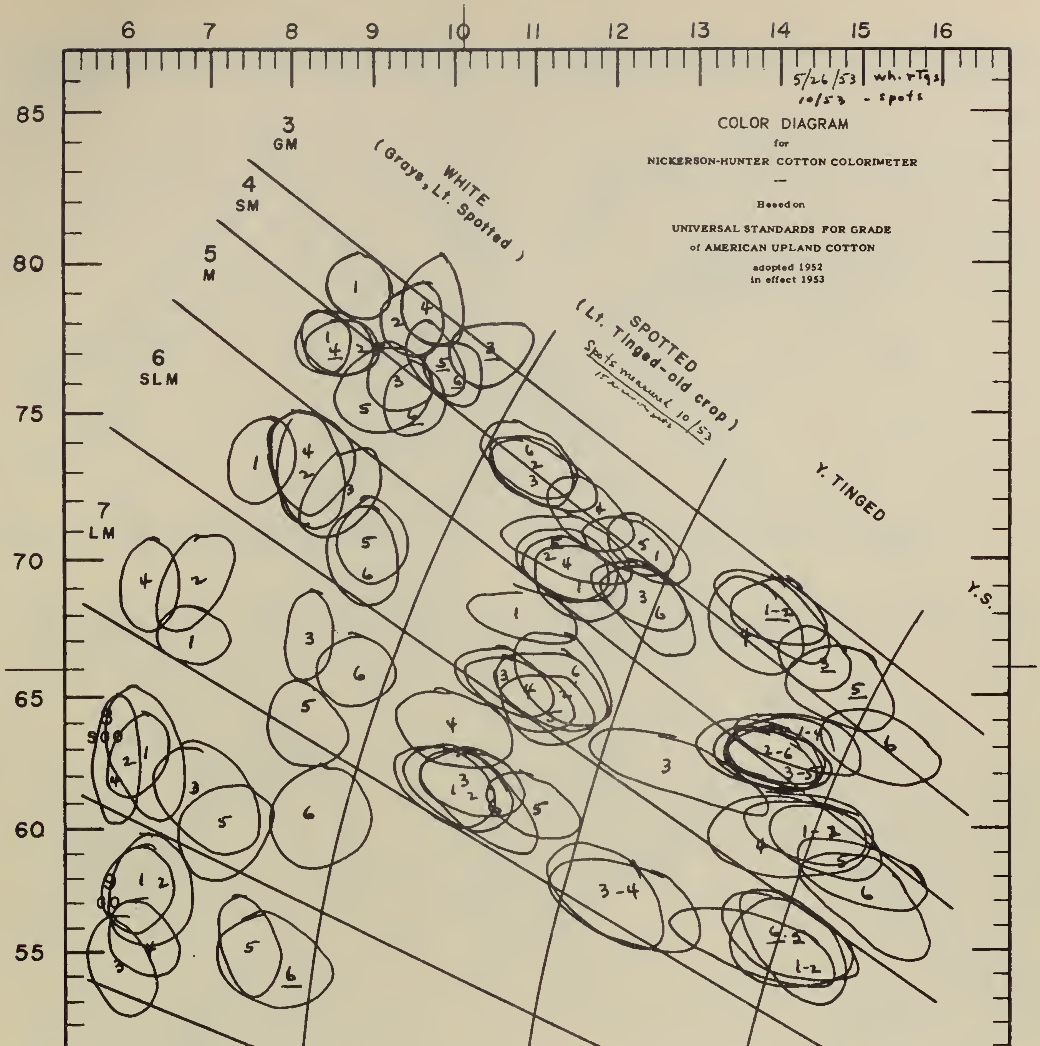
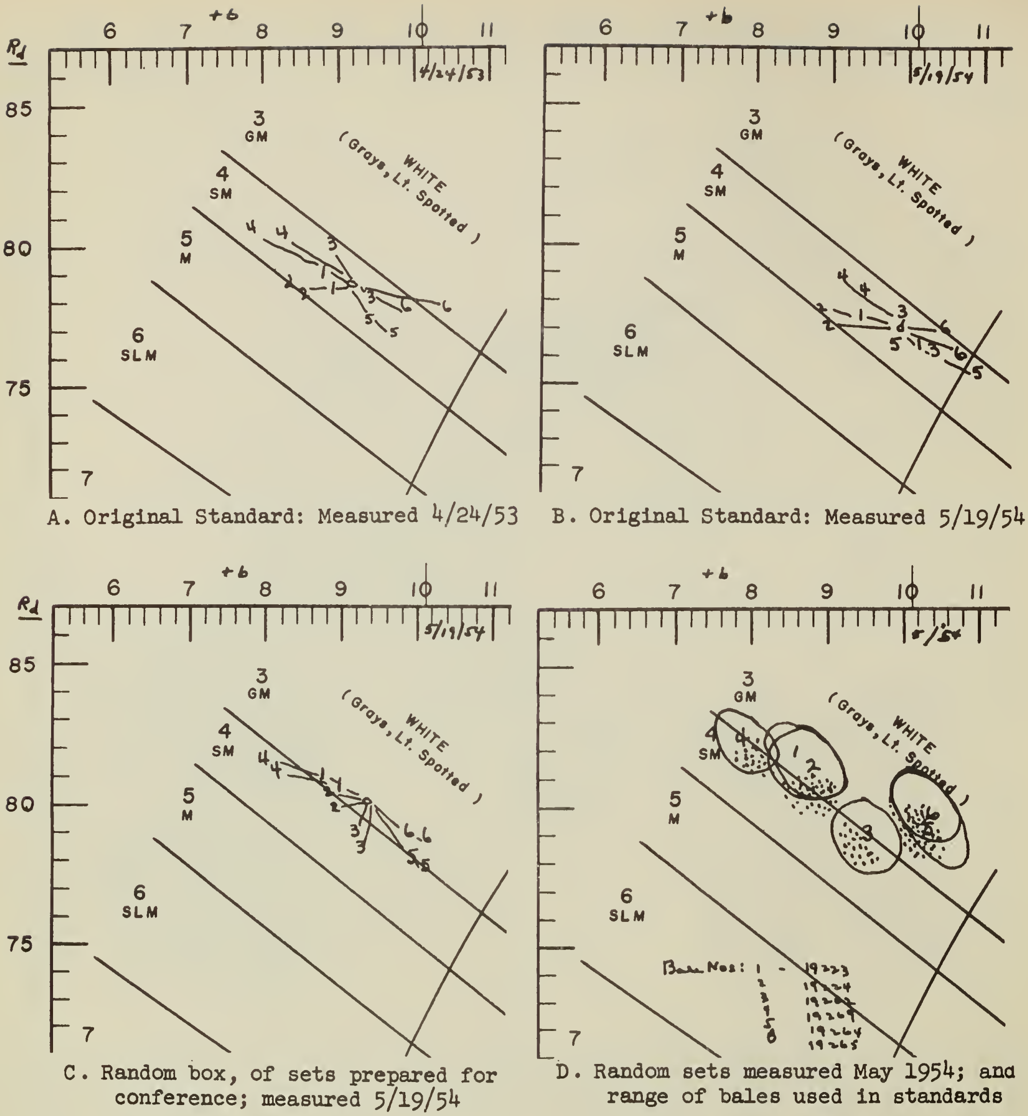


FIGURE 12.--ORIGINAL BALES, AFTER 1952 SUMMER STORAGE IN WASHINGTON.
These measurements, made November 1952, already indicate color change.



	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	129245	876309	68328	136293	136004	695464	367656	677808	19191	32374	19081	2597143	13427	11667
2	146897	149430	1084395	879593	136005	695564	19192	499916	10842	2771	19081	13193	13427	11667
3	19220	17534	849922	825	372322	1350315	19193	677455	19108	19181	703777	13155	17417	18218
4	588016	564143	405229	1667914	7797614	608667	19159	19118	19108	19122	380046	2597143	24078	18218
5	19067	178953	2644949	22838	2446522	13121	542617	677808	10891	250578	19090	13155	2694155	18600
6	19066	172953	31601	2629166	13115	13120	19193	550024	179735	2771	713627	13173	13369	18958

FIGURE 13.--BALES USED IN 1953 CONFERENCE BOXES. Underlined bale positions already had to be replaced because of color change from bales in original box.



A. Original Standard: Measured 4/24/53

B. Original Standard: Measured 5/19/54

C. Random box, of sets prepared for conference; measured 5/19/54

D. Random sets measured May 1954; and range of bales used in standards

FIGURE 14.--COLOR OF GOOD MIDDLING STANDARDS. A, Original, measured April 1953; B, Original, measured May 1954 (already shows considerable yellowing); C, Random box from sets prepared for 1954 conference, measured May 1954; D, Random sets measured May 1954, together with range of entire bales as used in standards.

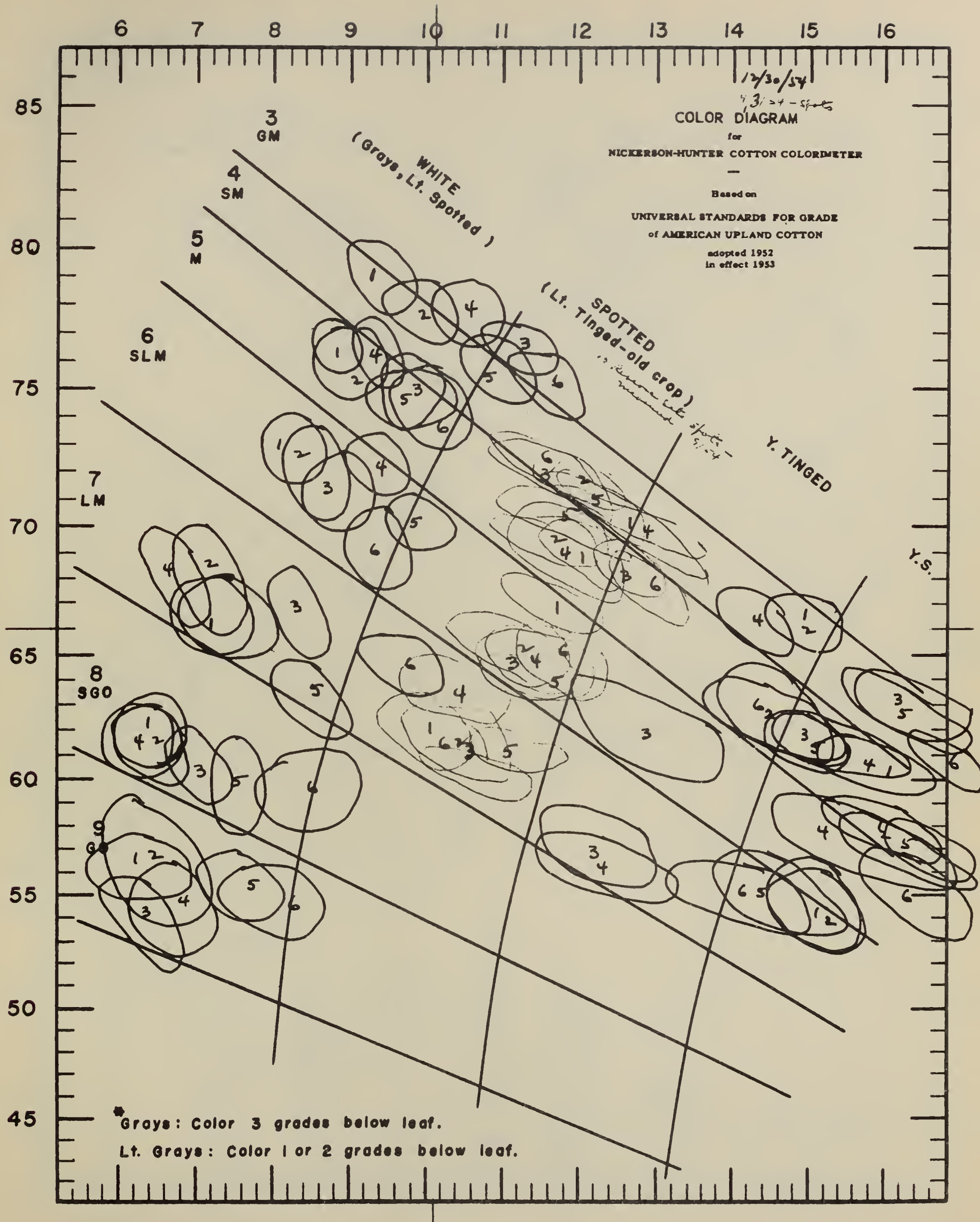


FIGURE 15.--RANGE OF 10 KEY SETS OF 1953 WHITE AND TINGED STANDARDS BOXES UNOPENED UNTIL MEASURED DECEMBER 1954, AND 15 SETS OF SPOTTED GUIDE BOXES MEASURED SEPTEMBER 1954.

Note continued yellowing as compared to either figure 8, the original standards bales, or figure 13, the same samples in 1953.

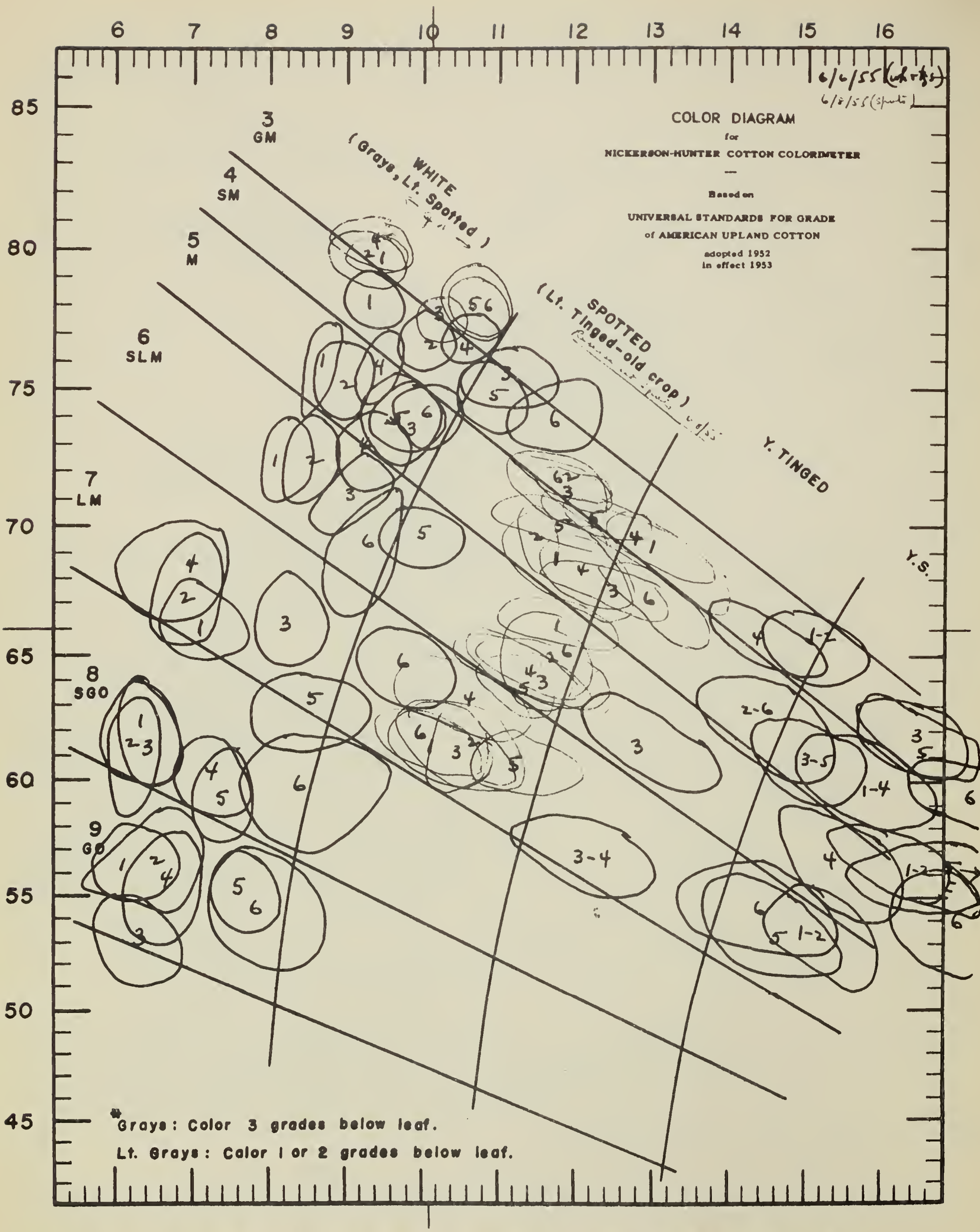
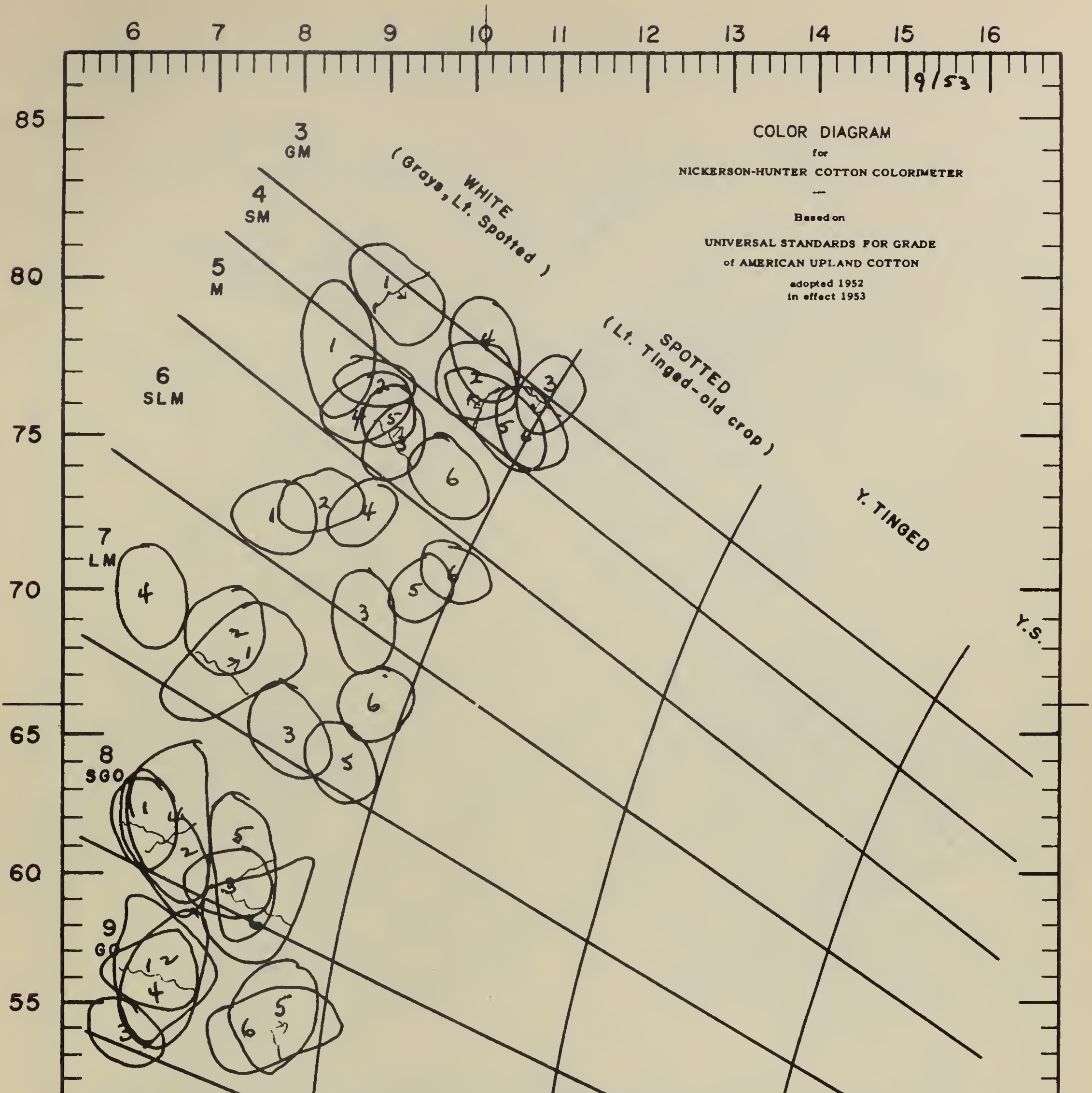


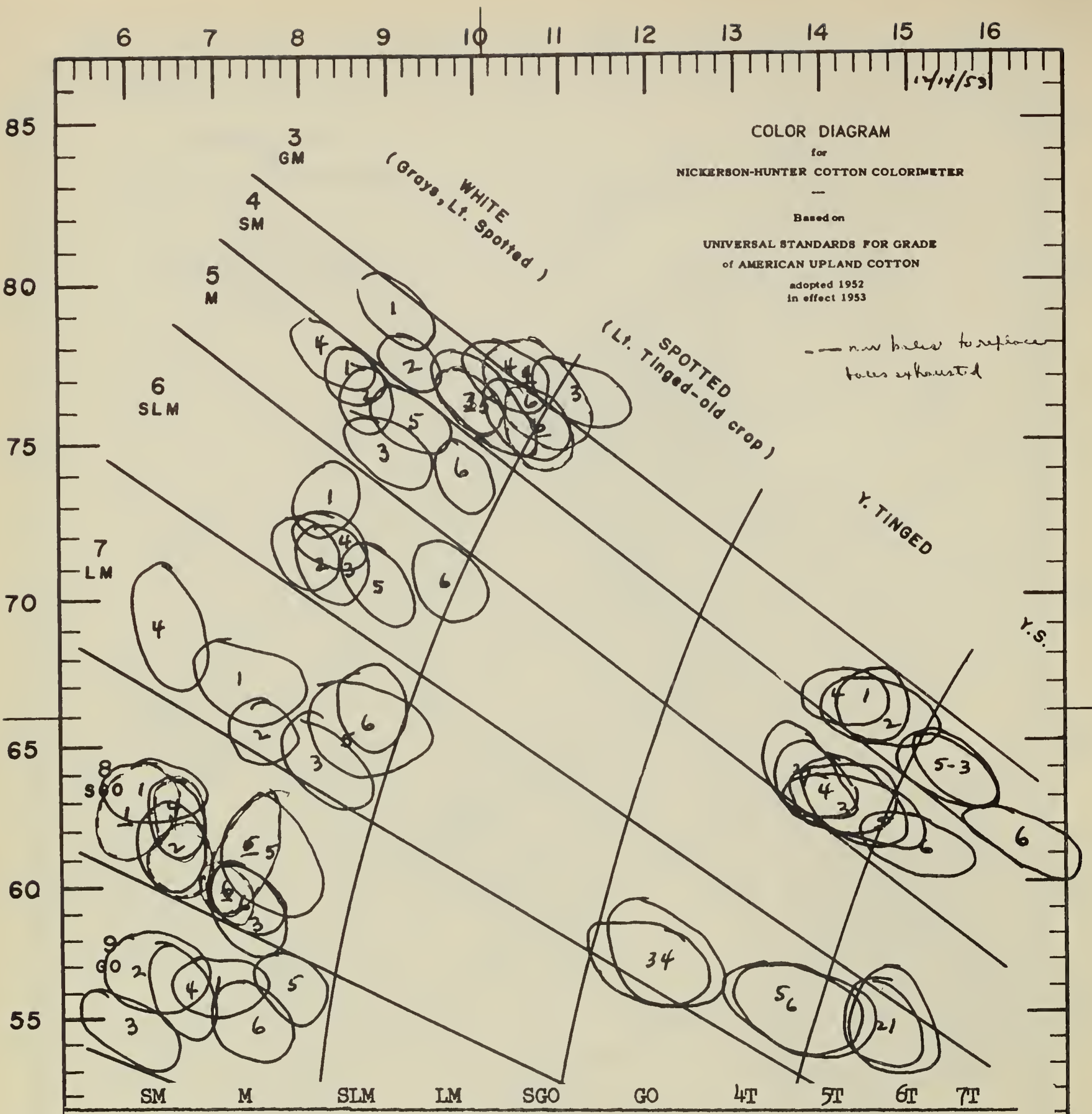
FIGURE 16.--RANGE OF 15 KEY SETS OF 1953 STANDARDS, AND OF RESERVE SETS OF SPOTTED BOXES, AS REMEASURED JUNE 1955.

Note continued yellowing as compared to figures 8, 13, and 15.



	GM	SM	M	SLM	LM	SGO	GO
1		129244	564145	161412	136293) 251320)	136004) 740337)	695464
2		1373142	145062) 1071335)	1079748	19162	740338) 136005)	695565
3		15294	17312) 354251)	1353442	34706	19134	1350315
4		588046	19160	19178	19138	418829) 7791614)	608667) 871810) 861594)
5		19067	19177	19132	19168	426541) 2446522)	13121
6		19066	19130	19114	19129	266105) 226508)	13120) 13155)

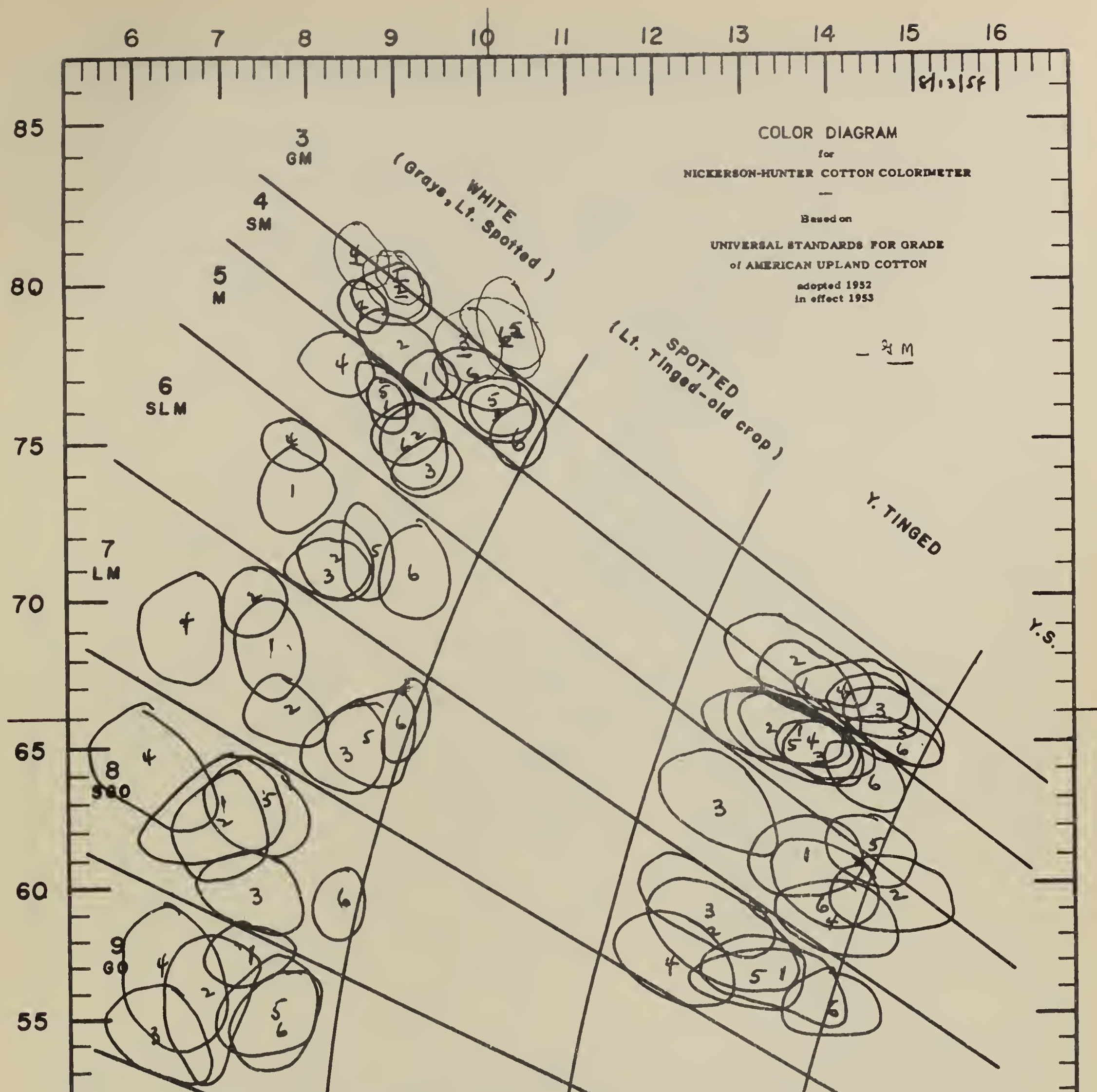
FIGURE 17.--RANDOM SETS OF WHITE GRADES BEFORE PHOTOGRAPHING, SEPTEMBER 1953.



	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	129244	128786	242500	251320	136004) 140337)	19103	19081	19080		11667
2	19124	145062	19198	19105	136005) 740337)	695564	19081	19069		11667
3	19208) 15294)	19203	1352024	19193	19134	1350315	703777	19074		18218
4	588014) 588016)	19205	19225	19138	7797614) 418829)	608667	380046	19080		18218
5	19068	19177	19131	19189	2446522) 426541)	13121) 19233)	19090	19078		18600
6	19066) 18338)	19130	19114	19129	2266108) 266105)	13120	713627	19079		18598

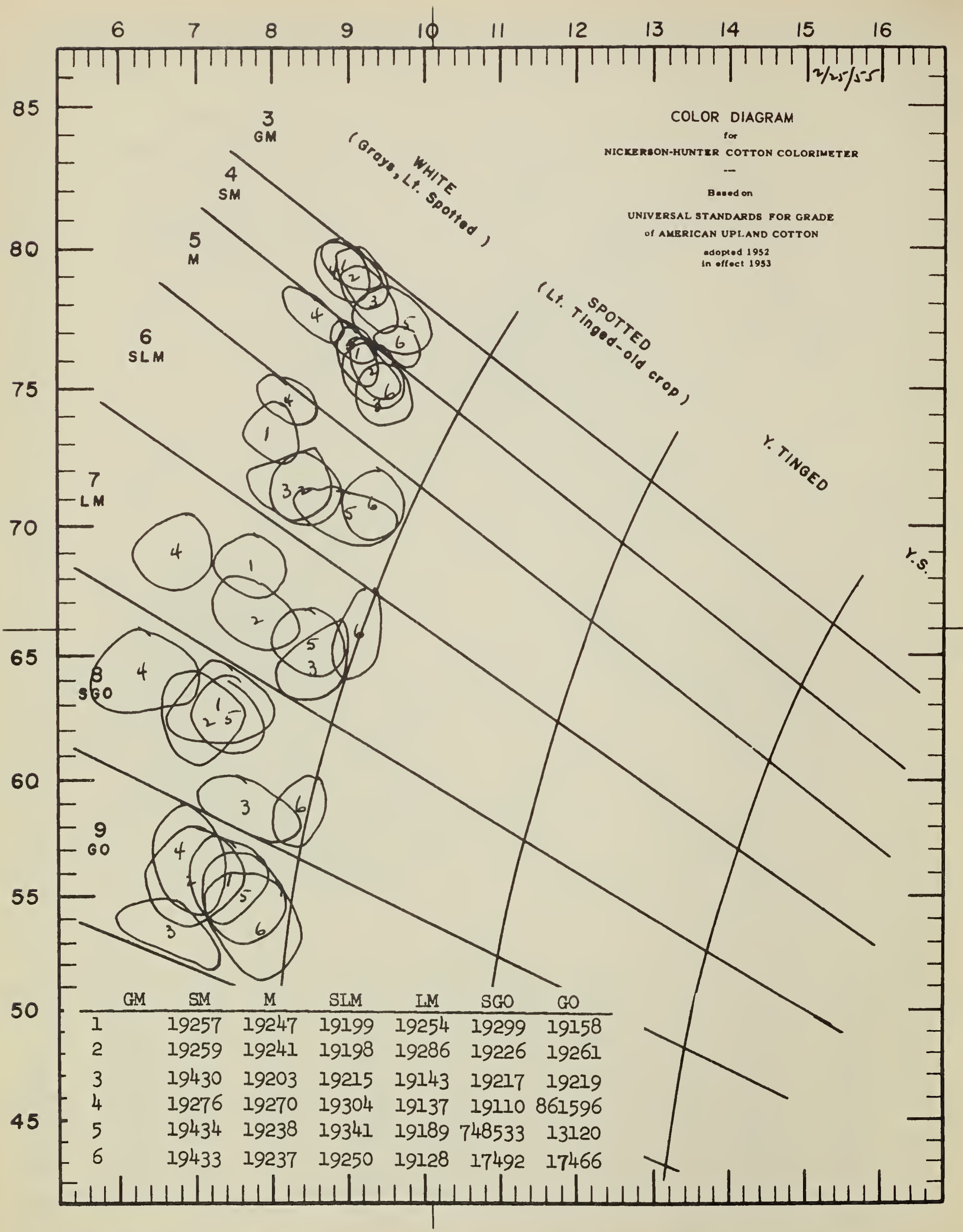
FIGURE 18.--RANDOM SETS OF WHITE AND TINGED GRADES BEFORE PHOTOGRAPHING, DECEMBER 1953.

Already the Tinged were so very much yellowed that the SLM Tinge could no longer be shipped, and the other Tinges were in question, as well as several White bales that were creeping toward the Spotted grades.



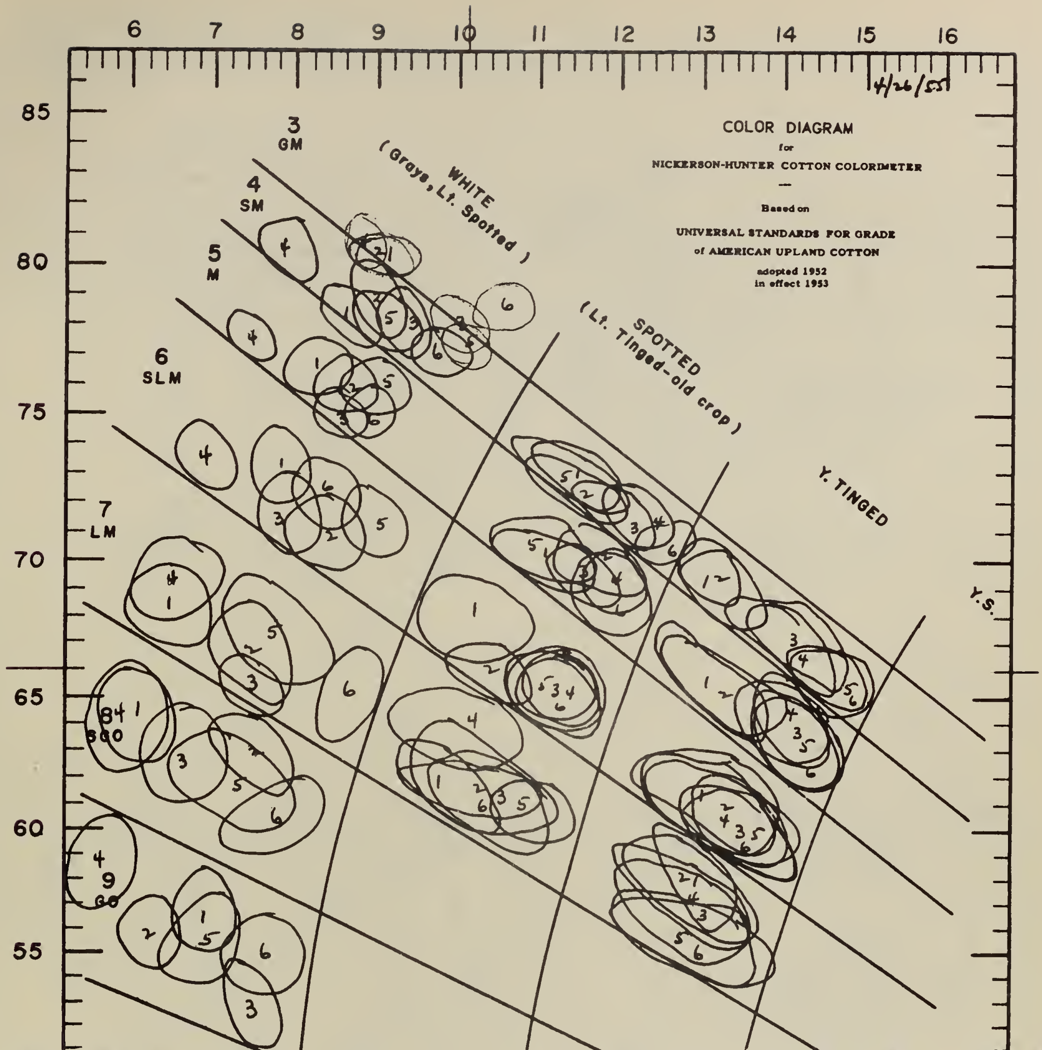
	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	19223	134648) 19257)	19247	19199	19254	19299) 740337)	19158	14360) 19273)	19358	19366	11642
2	19224	19124) 19258)	19241	19198	19251) 19286	19226	19261	19086	19361	19391	18557
3	19202	19208) 19207)	19203	19215	19143	19217	19219	19354	18927	19280	19272
4	19269	19267	19270) 19205)	19304	19137	19110	686767	380046) 19329)	19076	19075	18218) 19296)
5	19264	19068) 19234)	19238	19131	19189	748533	18758	19088	19093	19410	18601
6	19265	18338) 19235	19237	19250	19128	17492	13120) 19466)	759365	19359	19282	18600

FIGURE 19.--RANDOM SETS BEFORE PHOTOGRAPHING, AUGUST 1954.



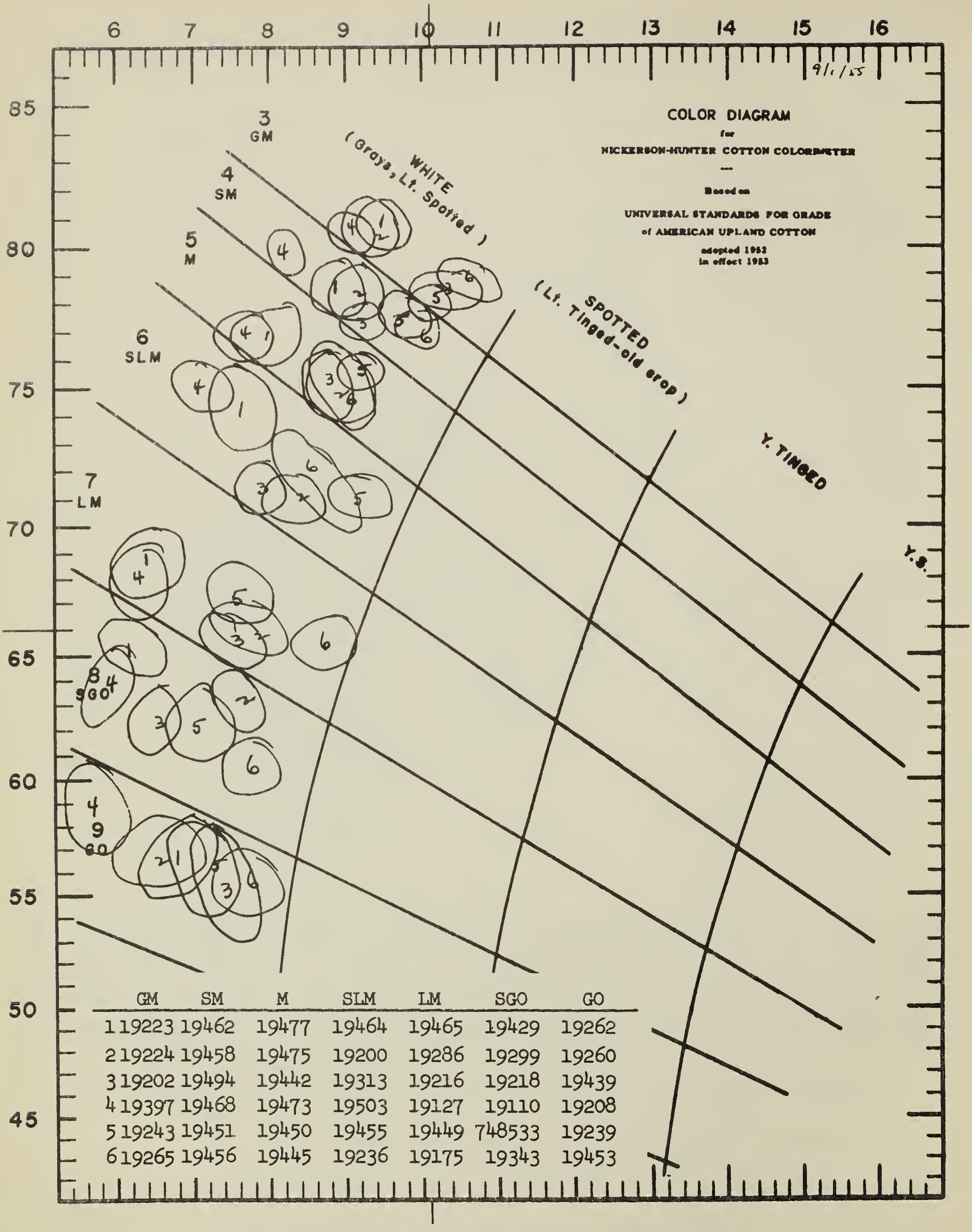
	GM	SM	M	SLM	LM	SGO	GO
1		19257	19247	19199	19254	19299	19158
2		19259	19241	19198	19286	19226	19261
3		19430	19203	19215	19143	19217	19219
4		19276	19270	19304	19137	19110	861596
5		19434	19238	19341	19189	748533	13120
6		19433	19237	19250	19128	17492	17466

FIGURE 20.--RANDOM SETS BEFORE PHOTOGRAPHING, FEBRUARY 1955.



	GM	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	19223	19462	19476	19199	19465	19429	19262	19180	18556	18998	32374	19327	19347	17417	19272
2	19224	19458	19475	19200	19286	19299	19260	19192	677816	250517	2771	19327	19347	17417	19272
3	19202	19430	19442	19313	19216	19218	19439	19193	499916	10842	19181	19086	19361	19084	18557
4	19397	19468	19473	19472	19137	19110	19308	19193	19118	19108	19122	19086	19361	19084	18557
5	19243	19451	19450	19455	19449	748533	19239	19180	18556	10891	250578	255482	2657539	19297	18601
6	19265	19456	19445	19236	19175	19343	19453	542617	677808	19108	2771	255482	2657539	19297	18601

FIGURE 21.--RANDOM SETS BEFORE PHOTOGRAPHING, APRIL 1955.



	GM	SM	M	SLM	LM	SGO	GO
1	19223	19462	19477	19464	19465	19429	19262
2	19224	19458	19475	19200	19286	19299	19260
3	19202	19494	19442	19313	19216	19218	19439
4	19397	19468	19473	19503	19127	19110	19208
5	19243	19451	19450	19455	19449	748533	19239
6	19265	19456	19445	19236	19175	19343	19453

FIGURE 22.--RANDOM SETS BEFORE PHOTOGRAPHING, SEPTEMBER 1955.

THIS PAGE FOLLOWS FIGURE 22

Table 1.--Number of samples put up out of typical 1956 standards bales.

Bale position	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	1416	1404	1188	1044	1164	1836	1272	1212	1572	1020	1572
2	1980	1968	1764	984	1296	1212	1044				
3	1404	1488	1236	1380	1428	1776	1200	1272	(1042M 451Y	1368	(828M 252Y
4	1188	900	1740	1080	816	1188	1728				
5	996	1488	1092	1188	1020	948	1320	1020	1212	1224	960
6	960	1092	1176	1092	1416	1404	888				
Average	1324	1390	1366	1128	1190	1394	1242	1168	1420	1204	1204

Table 2.--Number of large and small boxes of each grade shipped for three years 1953-1955, with total number of samples* required for each bale position.

Year	No. shipped	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1953	Large boxes	-	744	873	831	690	426	292	138	150	130	116
	Small boxes	-	477	606	592	474	322	199	119	149	128	99
	Total samples	-	1965	2352	2254	1854	1174	783	395	449	388	331
1954	Large boxes	223	267	325	305	244	172	138	69	74	76	63
	Small boxes	115	261	316	303	263	181	129	78	84	77	70
	Total samples	561	795	966	918	751	525	405	216	232	229	196
1955	Large boxes	167	389	473	452	350	240	180	90	93	86	77
	Small boxes	121	378	451	447	392	256	195	82	91	87	81
	Total samples	455	1156	1397	1351	1092	736	555	262	277	259	235

* In White grades, large boxes have 2 samples for each position, small boxes have 1 sample.

NOTE: The information in the above two tables makes it possible to estimate amount of stock for current and future needs.

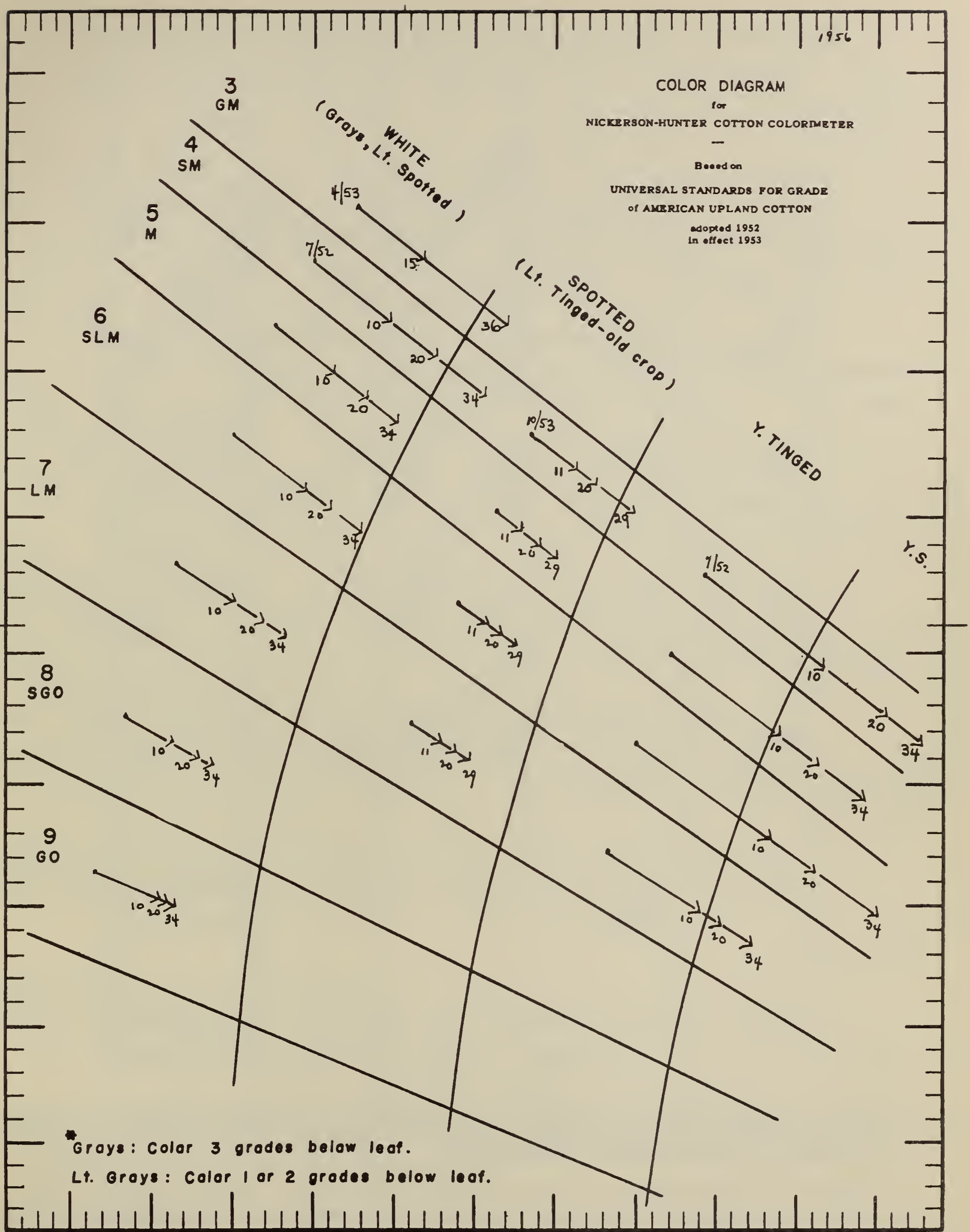


FIGURE 23.--AVERAGE COLOR CHANGE IN STORAGE FOR ORIGINAL STANDARDS AND GUIDES: 36 MONTHS FOR GM WHITE, 34 MONTHS FOR SM TO GO WHITE AND SM TO LM TINGE, 29 MONTHS FOR SPOTTED. The number of months between measurements is indicated below each arrow.

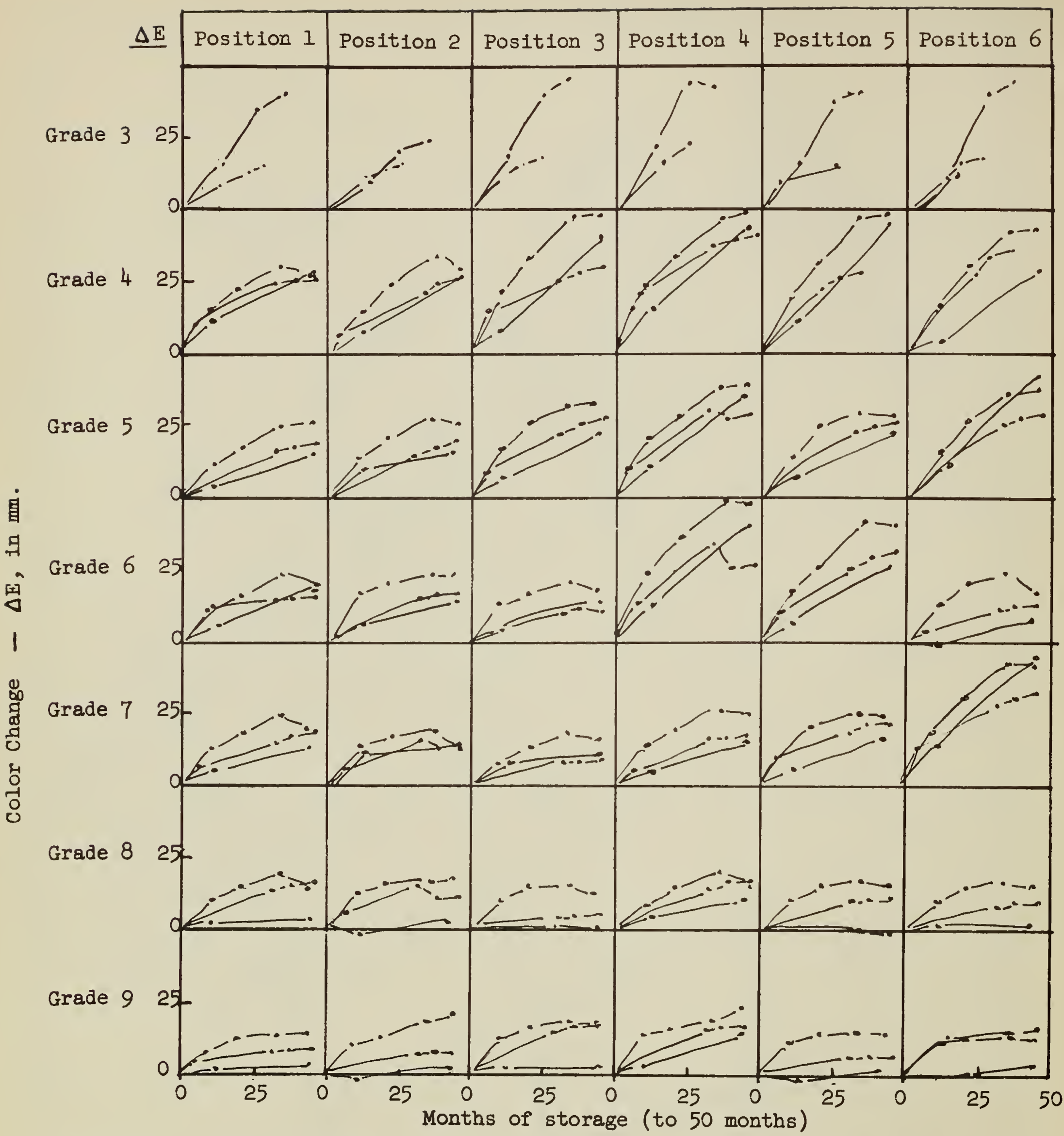


FIGURE 24.--COLOR CHANGE OF WHITE GRADE STANDARDS IN STORAGE INDICATED IN UNITS OF COLOR DIFFERENCE, ΔE, (MEASURED IN mm. OF CHANGE ON INSTRUMENT GRADE DIAGRAM) BY NUMBER OF MONTHS HELD IN WASHINGTON.

Change is illustrated for each of 6 bale positions in standard grades. Top grades change more than low grades, and there seems more levelling off by the second year for the lower than for the higher grades.

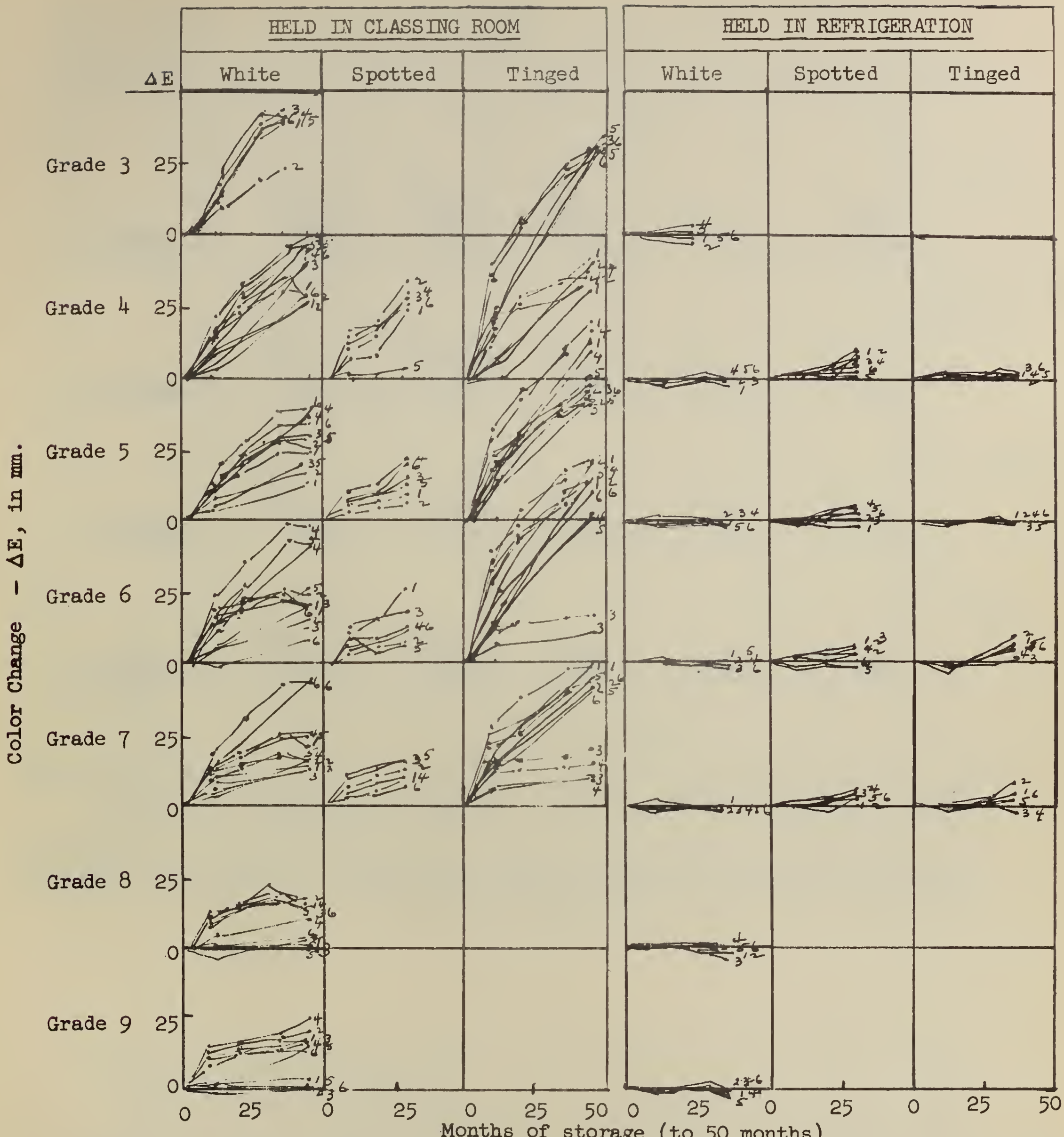


FIGURE 25.--COLOR CHANGE, ΔE, BY MONTHS OF STORAGE, INDICATED FOR EACH BALE IN WHITE, SPOTTED, AND TINGED GRADES HELD IN WASHINGTON UNDER CLASSING ROOM CONDITIONS, AND UNDER REFRIGERATION AT ABOUT 38°.

Refrigeration either slows down, or inhibits, color change. A controlled experiment, under several conditions of humidity and temperature, will be carried out 1956-1959 on cottons accepted at 1956 conference, so that by 1959 it should be possible to specify optimum conditions for temperature and humidity control for storing cotton standards. These are not now known.

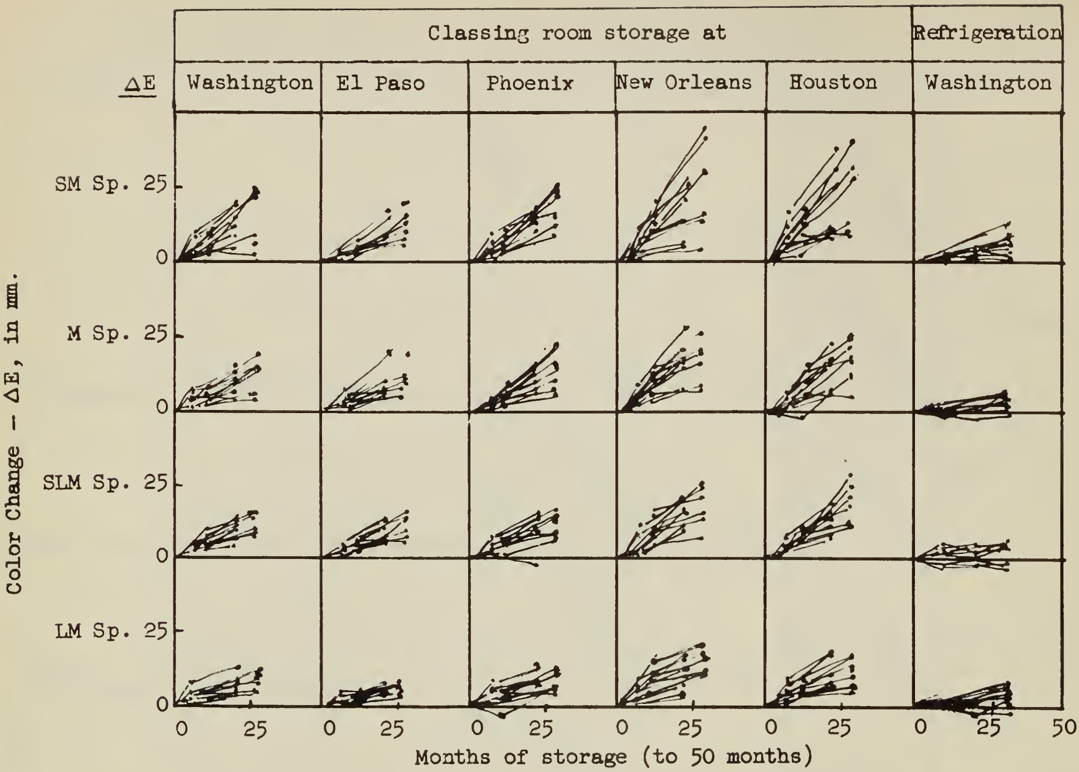
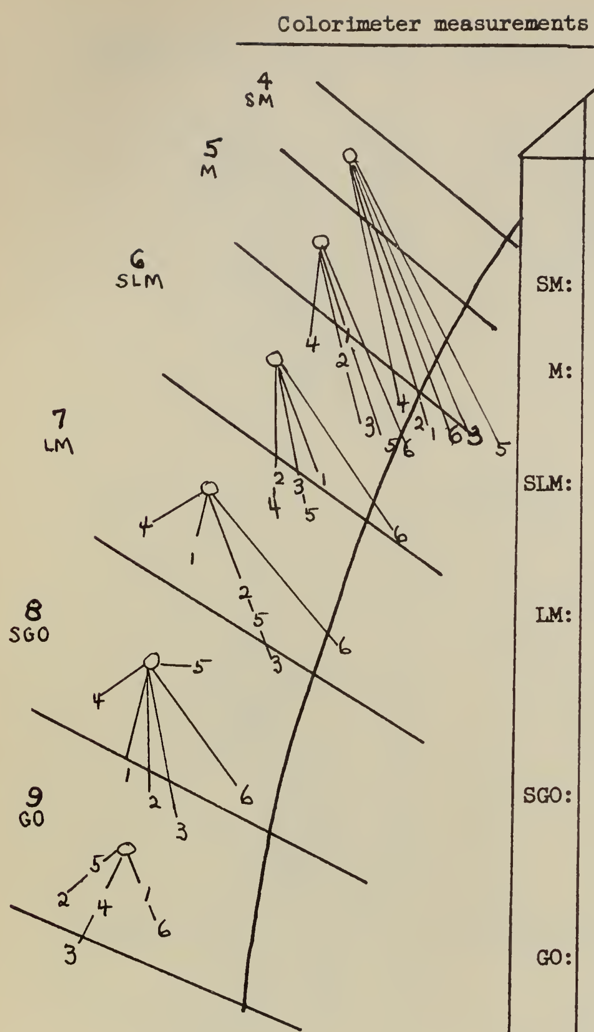


FIGURE 26.--COLOR CHANGE, ΔE, BY MONTHS OF STORAGE, IN SETS OF SPOTTED GUIDE BOXES STORED IN SEVERAL LOCATIONS SINCE 1953 COTTON GRADE STANDARDS CONFERENCE.

Following storage in five classing rooms of Cotton Division and in refrigeration, about 38°, some sets were measured 8/53, 4/54, and 5/55 (a maximum of 21 months), others 8/53, 7/55, and 3/56 (a maximum of 29 months).



Classer Comparisons

	Classer 1 (HCS)	Classer 2	Classer 3
SM:	M 1 grade low	SM	M except #6
M:	SLM 1 grade low	M	M
SLM:	1/2 grade low	SLM	SLM
LM:	SGO dusty	LM	LM
SGO:	GO dusty	SGO	SGO
GO:	GO equal dusty	GO	GO

FIGURE 27.--COLORIMETER AND CLASSER COMPARISONS ON A TYPICAL SET OF WHITE STANDARDS RETURNED AFTER USE.

Although color definitely goes down as standards are used in classing rooms, classers seldom recognize it, for they recognize leaf and then assume color is unchanged. Color classed against such boxes may be too easy by a grade or more.

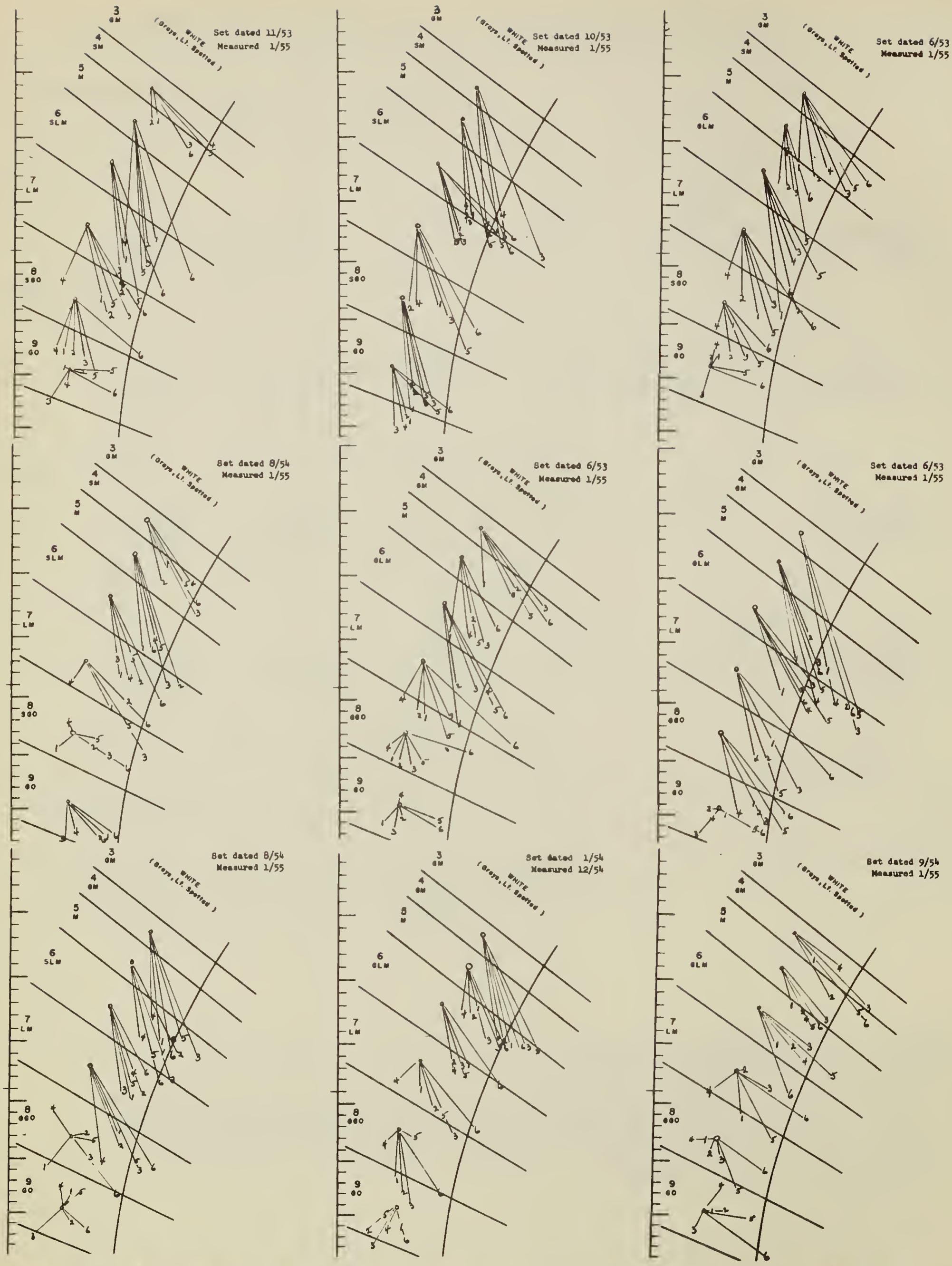


FIGURE 28.--MEASUREMENTS ON SETS OF STANDARDS TYPICAL OF THOSE RETURNED AFTER USE.

Each set shown is from a different office, with each classing area represented. A study in 1955 of returned standards shows that this amount of color change through dustiness, from being open in a classing room while in use, is not uncommon for standards used a great deal. This change, so easily overlooked, even by experienced classers, is another good reason why standards should not be used more than one season, sometimes no longer than one month. None of these boxes were more than 18 months old when returned for study. The dates of issue and of measurement after return are shown for each set.

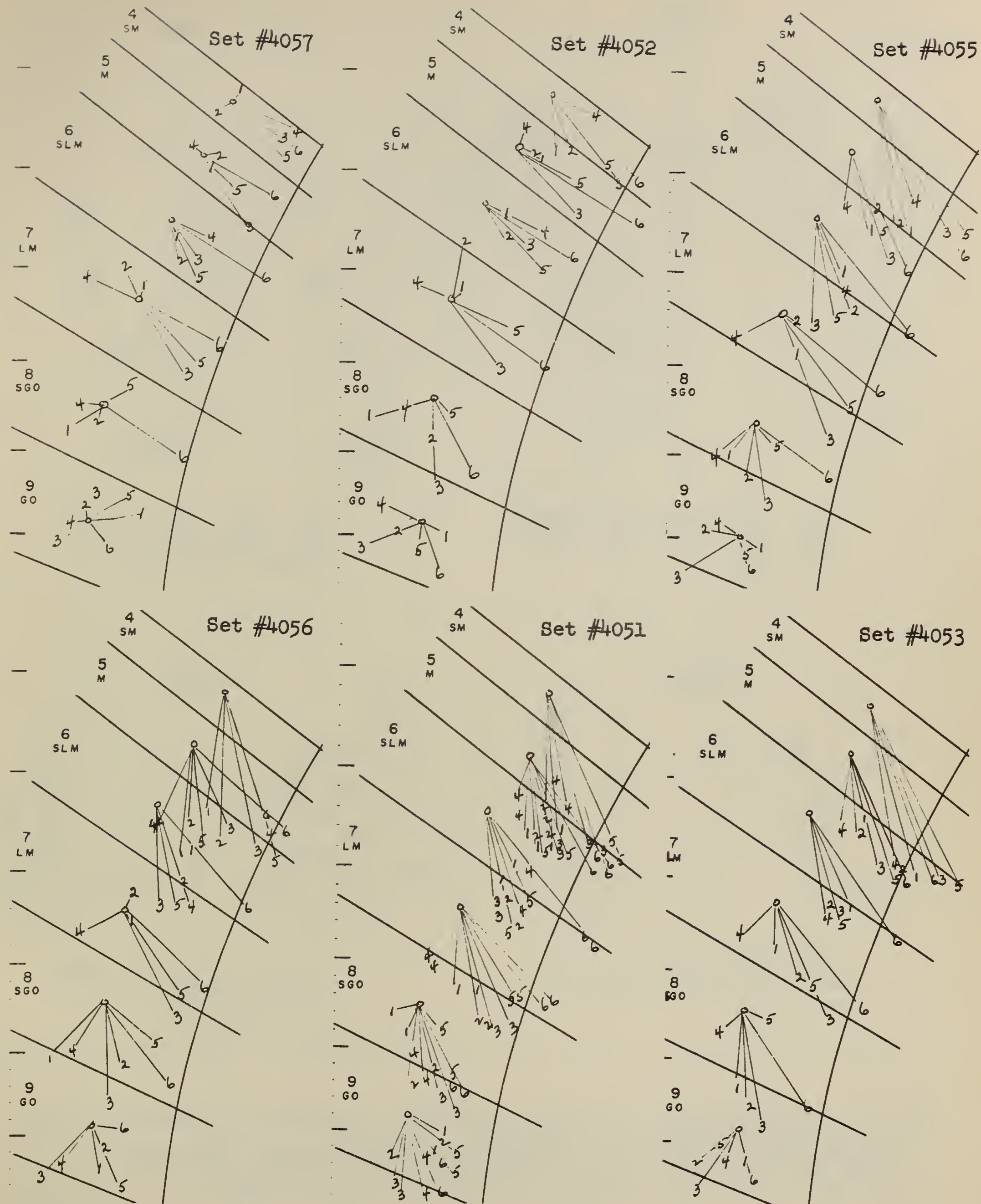
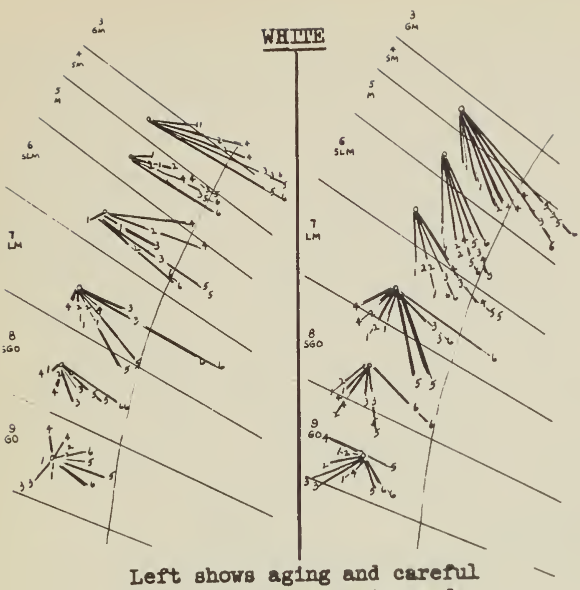
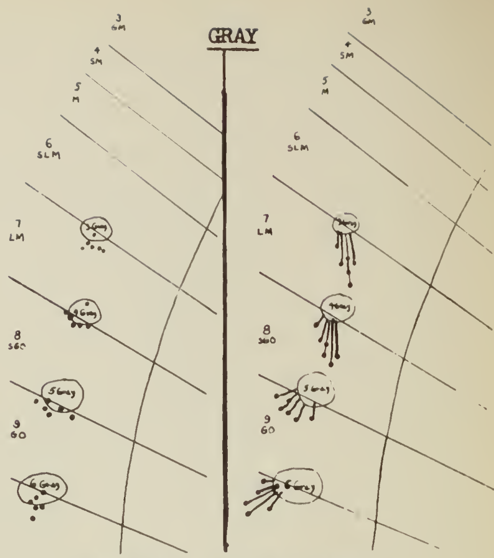


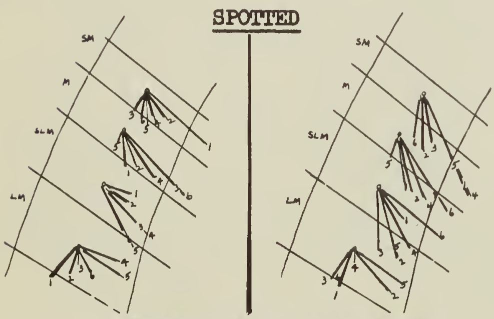
FIGURE 29.--MEASUREMENTS OF STANDARDS RETURNED AFTER USE IN ONE OFFICE IN ONE SEASON. Most of them show hard use. They are arranged to show increasing amount of change caused by use.



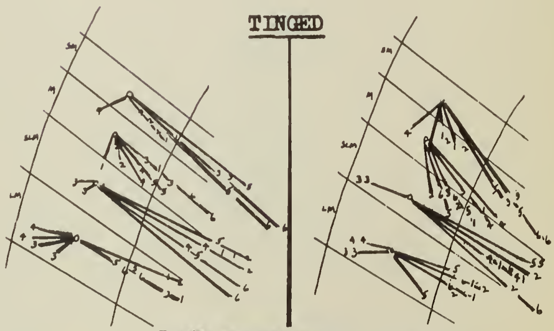
Left shows aging and careful use; right shows aging and hard use.



Left shows little change with aging; right shows change through use.



Left shows aging and careful use; right shows aging and hard use.



Left shows aging; right shows aging, and use of two top grades.

FIGURE 30.--MEASUREMENTS ON RETURNED STANDARDS, AFTER USE OF 18 MONTHS OR LESS.

Sets are shown in pairs to illustrate two types of change, yellowing by aging, and darkening by dustiness caused by use of standards.

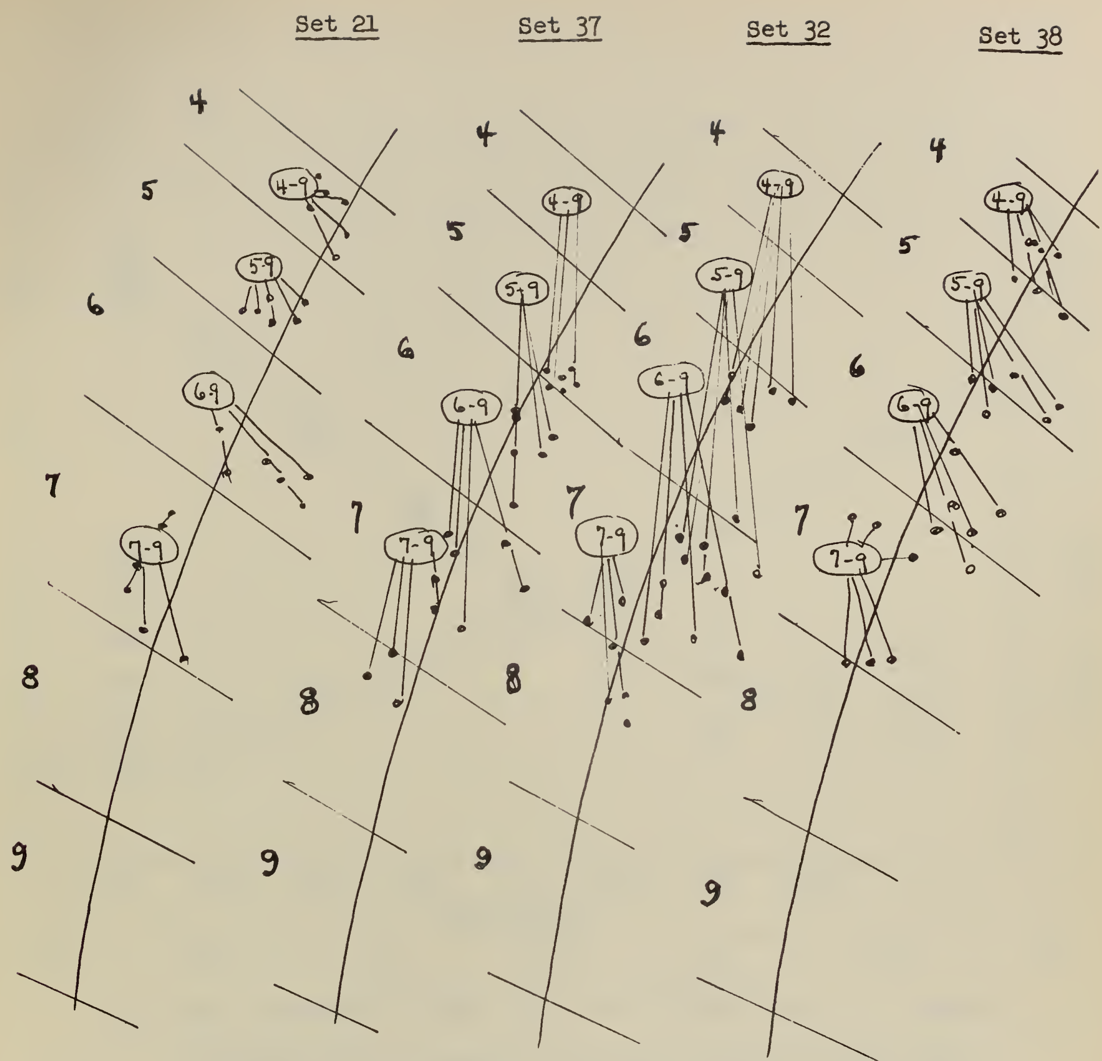


FIGURE 31.--COLORIMETRIC COMPARISONS ON TYPICAL SETS OF LIGHT SPOTTED BOXES RETURNED AFTER USE.

The grade number is circled at the color position of the bales originally used in these boxes. Set 21 shows little use; the others show change, the majority yellowing into Spotted color, also becoming low in color through dustiness. The figure 9 used with the grade number, is a code number for Light Spotted.

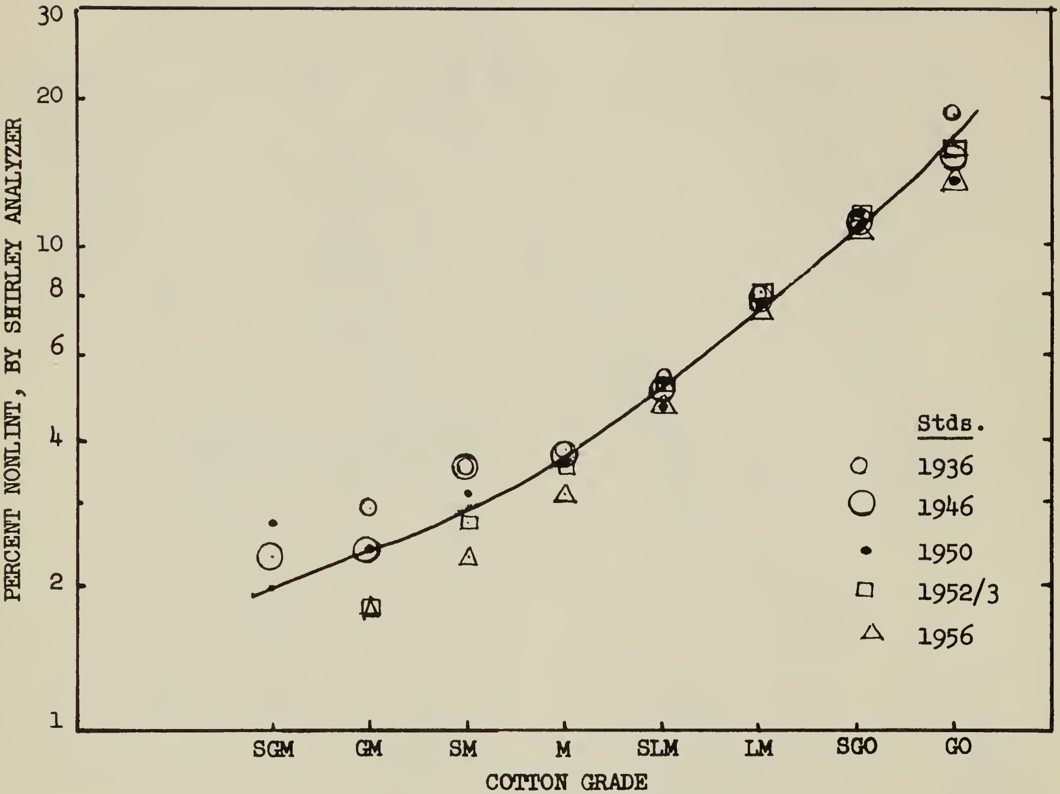


FIGURE 32.--TRASH ANALYSIS FOR BALES USED IN STANDARDS, 1936-1956.
See Note following table 4 for discussion and explanation.

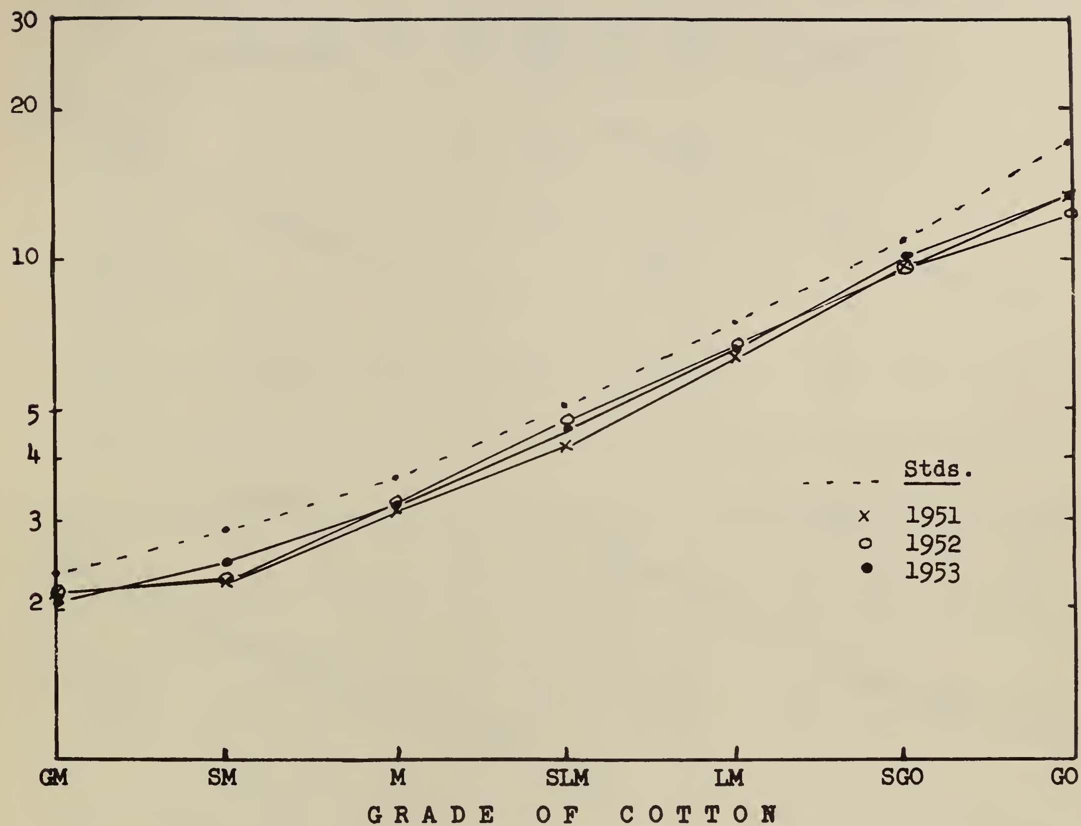


FIGURE 33.--TRASH (NONLINT) CONTENT OF COTTONS CLASSED IN WHITE GRADES: U. S. COTTON CROPS 1951-53.

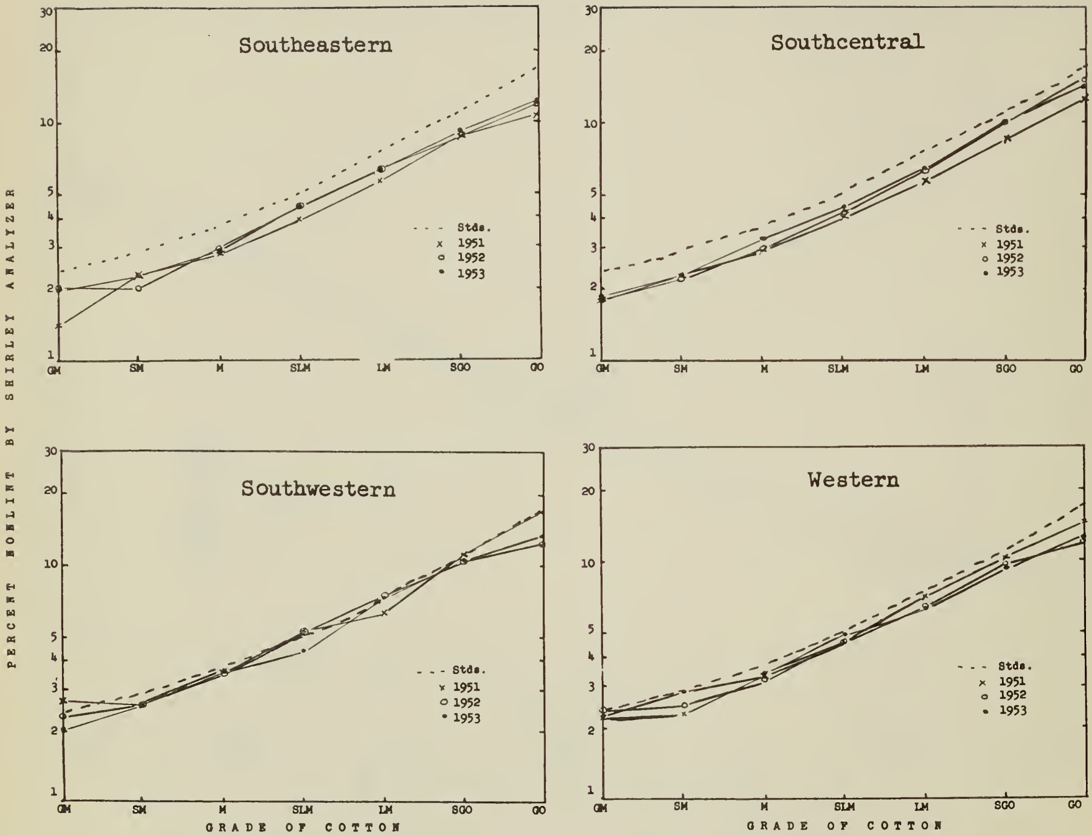


FIGURE 34.--TRASH (NONLINT) CONTENT OF COTTONS CLASSED IN WHITE GRADES: BY COTTON GROWING AREAS IN THE U. S., FOR THREE CROP YEARS.

Table 3.--Shirley Analyzer trash in grade standards bales, 1936, 1946, 1950, 1952/53, and 1956, and in grade surveys 1947, 1950, 1951, 1952, and 1953.

Year	GM	SM	M	SLM	LM	SGO	GO
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Stds. bales							
1936	2.9	3.6	3.8	5.4	8.1	11.0	18.6
1946	2.4	3.5	3.7	5.1	7.7	11.2	15.2
1950	2.4	3.1	3.6	4.7	7.6	11.7	13.5
1952/53	1.8	2.7	3.5	5.2	8.1	11.5	15.3
1956	1.8	2.3	3.1	4.7	7.3	10.7	13.3
Grade Survey							
1947	3.5	4.0	4.6	5.5	7.8	11.0	15.3
1950	1.8	2.7	3.5	5.1	7.2	11.4	15.4
1951	2.2	2.3	3.2	4.3	6.5	9.8	13.5
1952	2.2	2.3	3.3	4.8	6.8	9.6	12.1
1953	2.1	2.5	3.2	4.6	6.7	10.2	13.4

Table 4.--Shirley Analyzer trash for top and bottom of bales in 1956 standards.

Bale position	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Std.	2.4	2.9	3.7	5.1	7.6	11.0	17.0				
1	1.6	2.5	3.4	5.0	6.6	10.0	13.5	3.6	7.6	10.1	6.4
	1.6	2.2	2.8	4.2	6.8	10.9	13.3	3.9	6.3	11.9	6.2
2	2.2	2.3	2.7	4.7	6.5	11.6	12.2				
	2.8	2.0	3.0	5.0	6.7	10.9	12.8				
3	1.7	1.9	2.5	5.1	8.7	11.2	13.3	4.1	4.8	8.6	10.8
	1.2	1.7	2.3	5.6	7.8	11.1	11.2	4.2	4.2	10.3	11.0
4	2.1	2.3	4.0	5.8	8.4	10.0	12.2				
	2.2	3.0	4.0	5.0	8.7	9.1	12.3				
5	1.7	3.0	3.4	4.8	6.9	8.7	16.4	3.1	3.8	8.6	8.7
	1.7	2.8	3.0	4.1	7.1	8.7	17.7	2.9	4.0	7.4	8.7
6	1.3	2.0	3.3	3.5	7.3	14.2	12.7				
	1.6	1.9	3.0	3.5	6.3	11.8	12.5				
Average	1.8	2.3	3.1	4.7	7.3	10.7	13.3	3.6	5.1	9.5	8.6

NOTE: Compared to the average of past standards, bales for practically all 1956 grades are lighter in trash than intended when bales were purchased. Trash has had to be added to some boxes, but this has been kept to a minimum in order to hold to the principle of a natural standard.

Trash studies during the next three years (more intensive with a new Cotton Trash Meter) should provide information for judging whether current cleaning methods at the gin are resulting in so much less trash that adjustments need be made in standards.

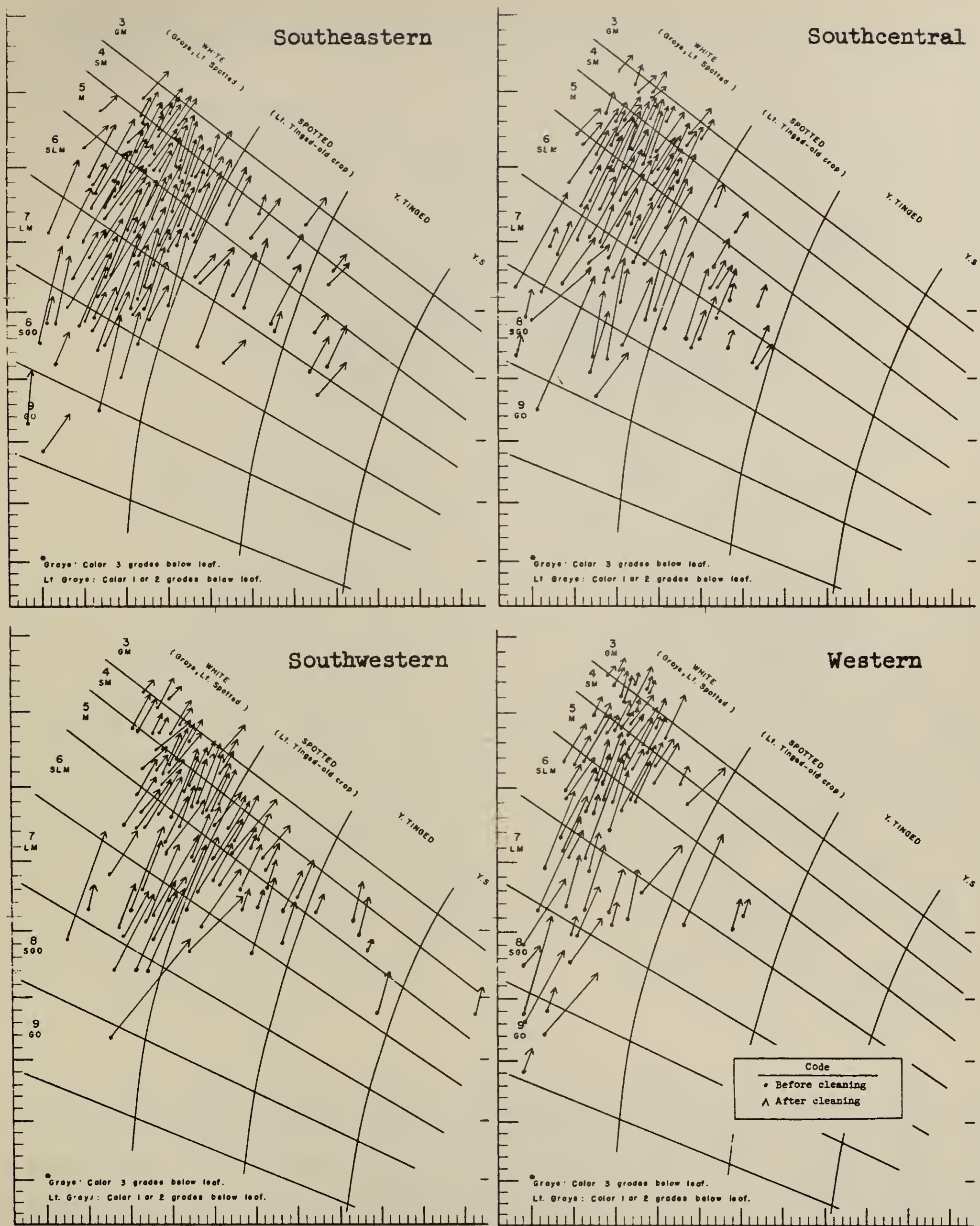
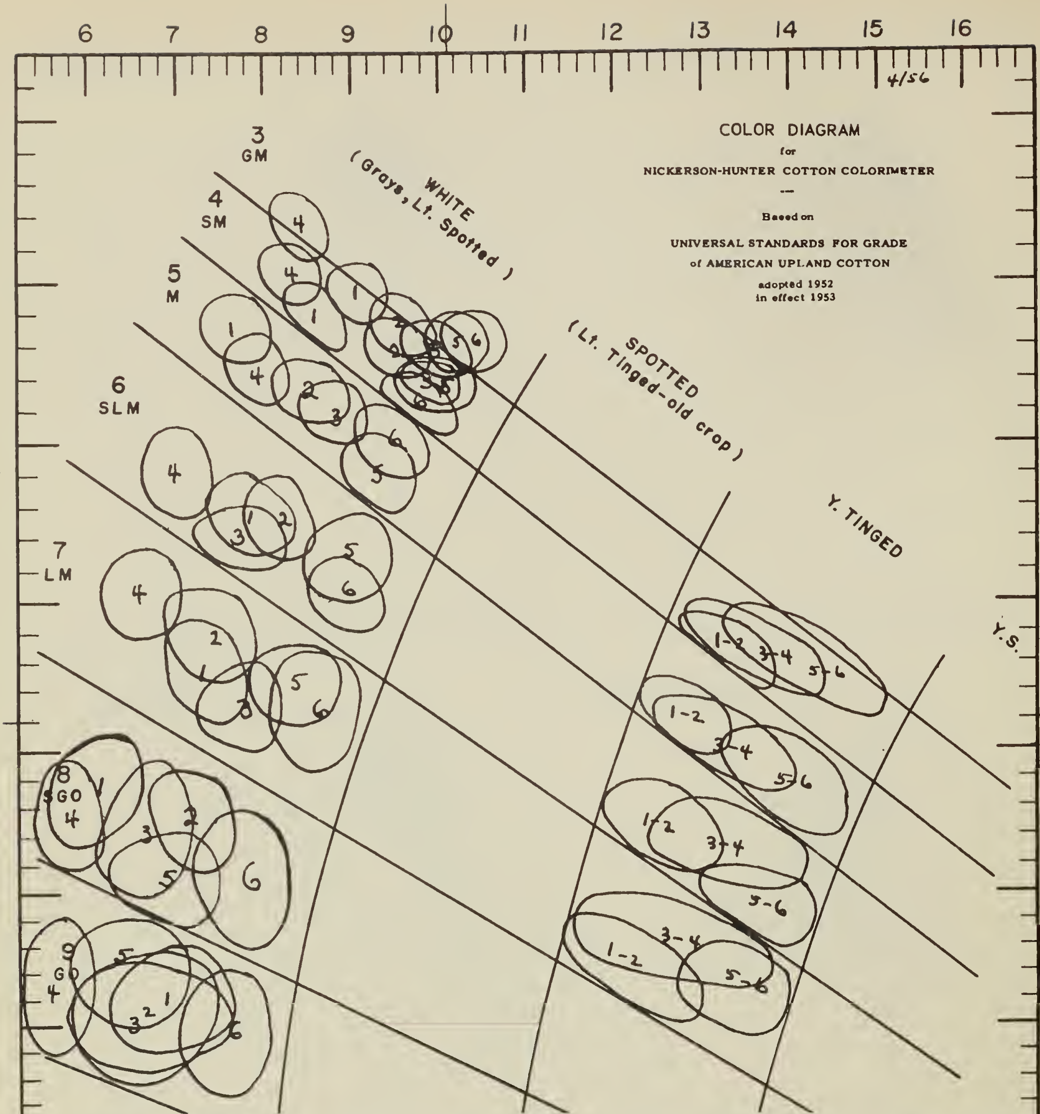


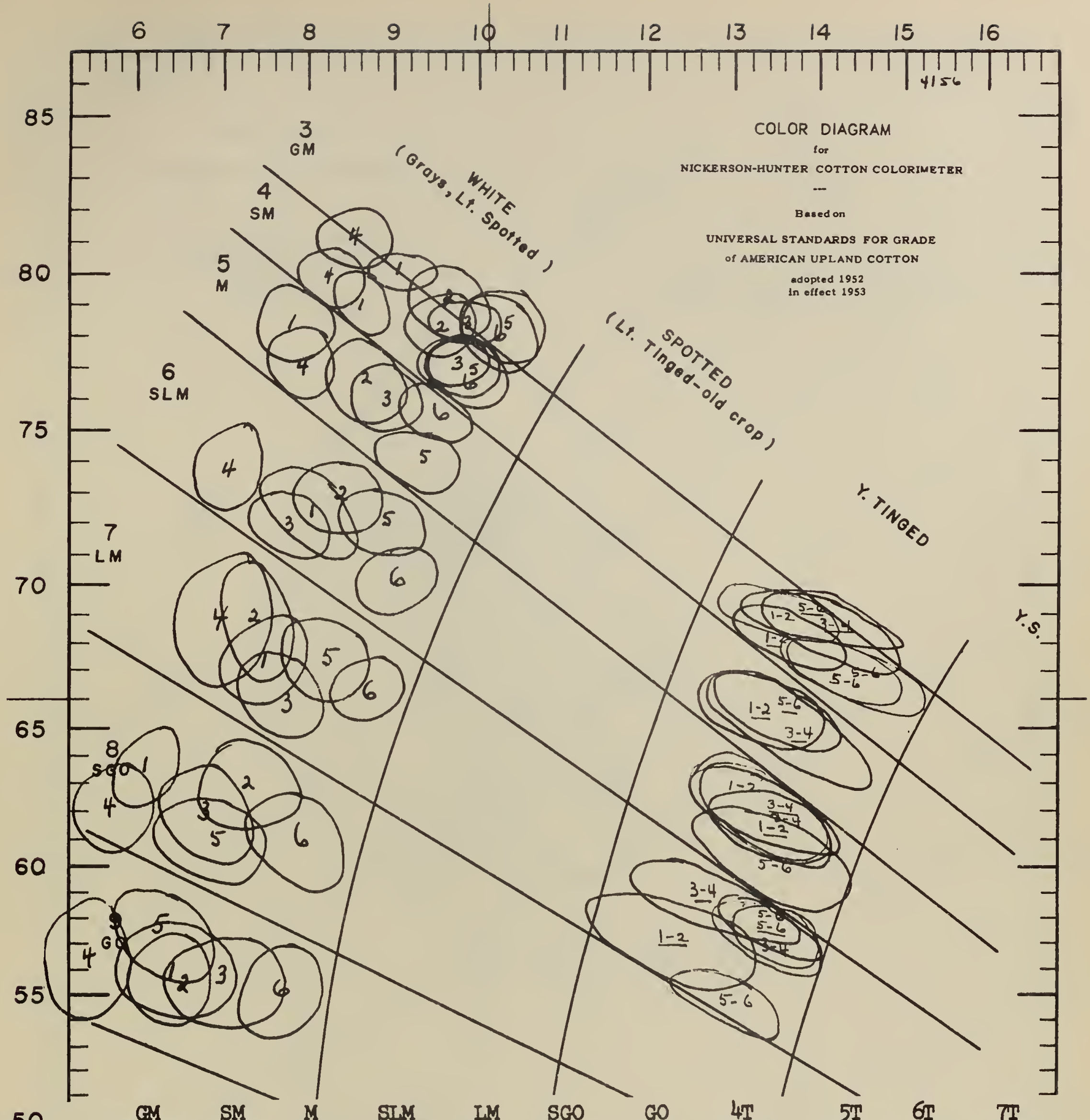
FIGURE 35.--COLOR OF LINT COTTON AFTER REMOVAL OF TRASH (NONLINT) CONTENT. Color improvement in typical samples from the 1952 crop is shown by measurements before and after cleaning on the Shirley Analyzer.



	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	19642	19567	19652	19478	19522	19673	19262	19690	19495	19390	19705
2	19566	19569	19606	19520	19481	19482	19261				
3	19595	19592	19587	19455	19349	19218	19352	19525	19658	19447	19692
4	19588	19573	19600	19636	19505	19670	19693				
5	19544	19580	19563	19511	19496	18153	19698	19700	19291	19490	19278
6	19542	19582	19564	19612	19127	18151	19703				

FIGURE 36.--RANGE OF COLOR IN 12-SAMPLE STANDARDS BOXES PUT UP FOR THE 1956 UNIVERSAL GRADE STANDARDS CONFERENCE.

These measurements were made on 110 sets of large boxes after they were put up for the conference.



	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	19642	19567	19652	19478	19522	19693	19262	19690	19495	19390	19705
2	19566	19569	19606	19520	19481	19482	19261	(367656		(19364	
3	19595	19592	19587	19485	19349	19218	19352	19525	19658	19447	19692
4	19588	19573	19600	19636	19505/311	19670	19693			(19280	(19368
5	19544	19580	19563	19511	19496	18153	19698	(19700	19291	19490	19278
6	19542	19582	19564	19612	19127	18151	19703	(19086		(19373	(18976
								2554856			(18562

FIGURE 37.--RANGE OF COLOR IN 6-SAMPLE GUIDE BOXES PUT UP FOR THE 1956 UNIVERSAL GRADE STANDARDS CONFERENCE.

These are based on 25 sets of small boxes. The same bales are used in both large and small boxes as long as the supply lasts, but in some cases, particularly in the Tinges, a second and even third bale had to be used to complete the large supply of boxes needed for the 1956 standards. (Bale numbers are given for USDA convenience.)

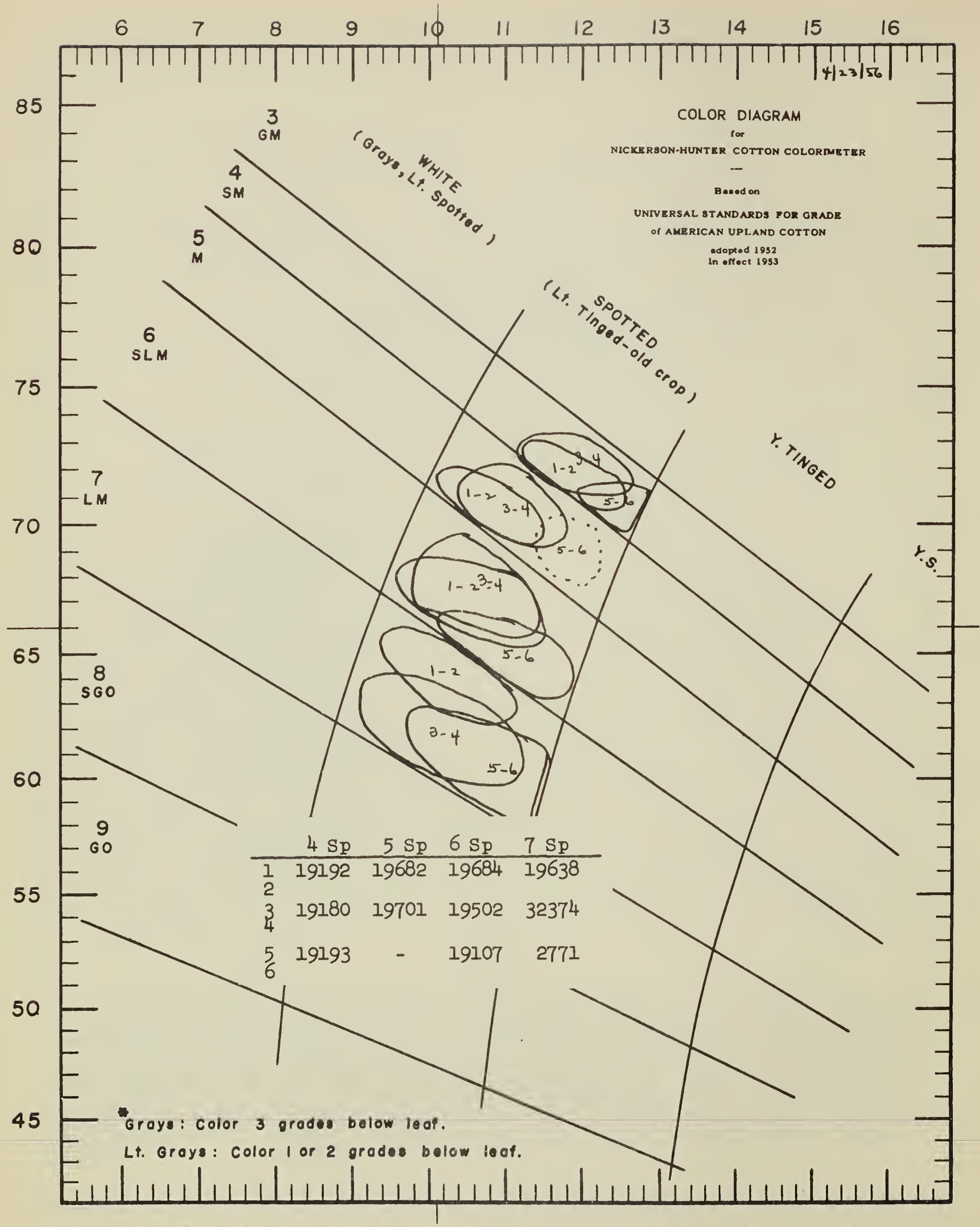


FIGURE 38.--RANGE OF COLOR IN SPOTTED BOXES PUT UP FOR THE 1956 CONFERENCE. For Middling Spotted the 5-6 position is intended to be as shown in the dotted area. The bale put up in this position was not satisfactory, and a new bale was thereafter bought to replace it. It had not been received when this diagram was prepared.

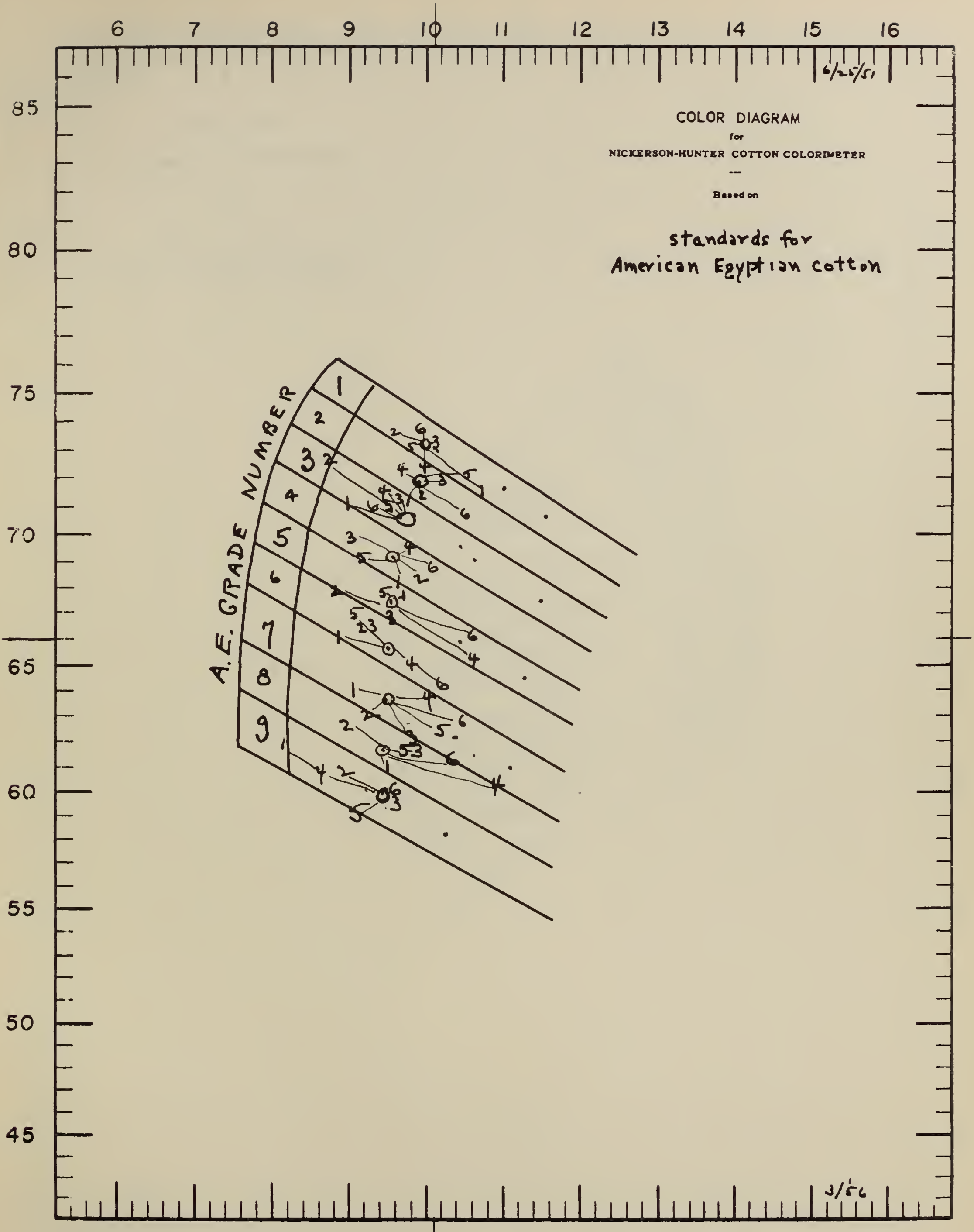


FIGURE 39.--ORIGINAL STANDARDS FOR GRADE OF AMERICAN EGYPTIAN COTTON, 1951.

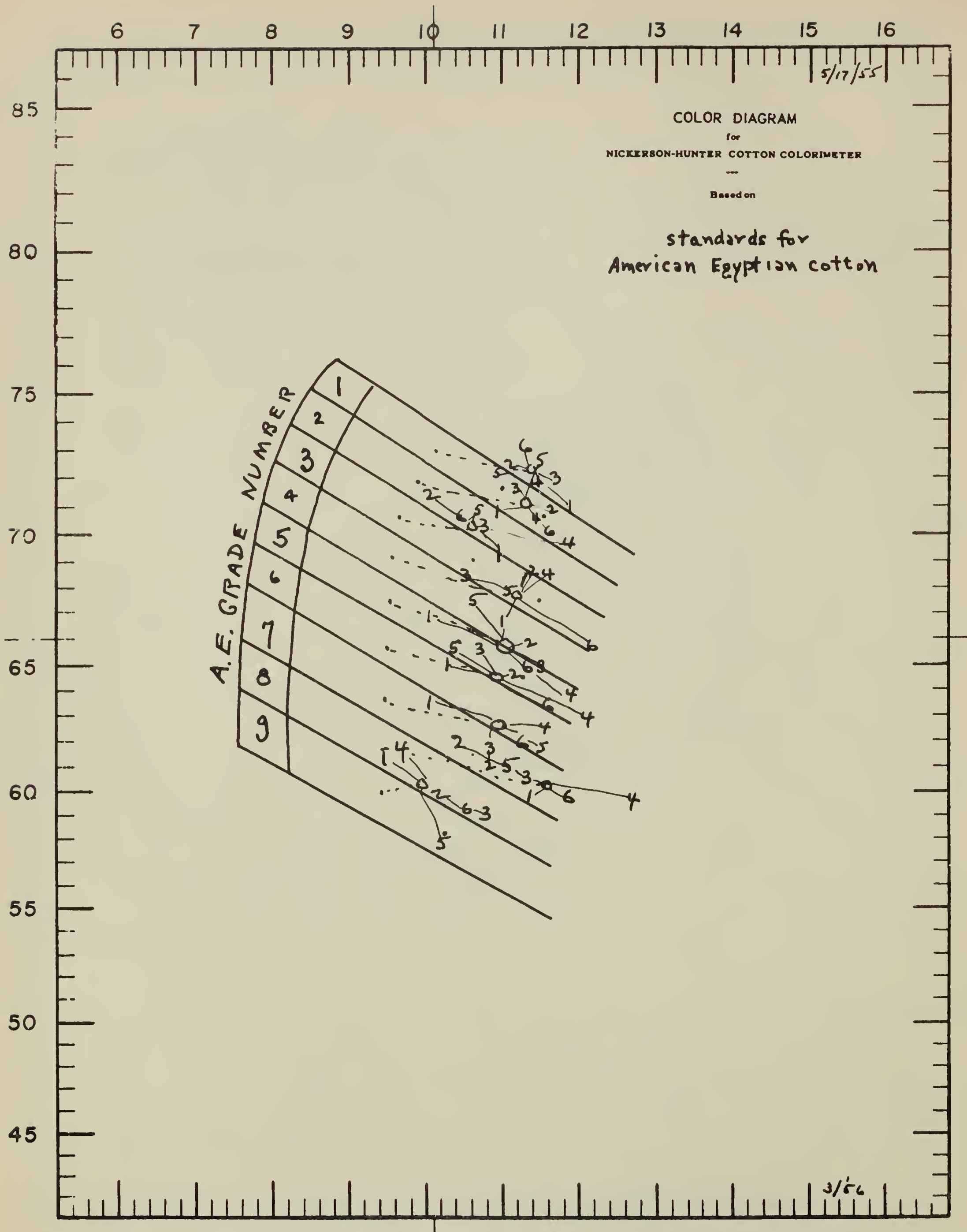


FIGURE 40.--ORIGINAL STANDARDS FOR GRADE OF AMERICAN EGYPTIAN COTTON, AS MEASURED MAY 1955, FOUR YEARS AFTER IT WAS ORIGINALLY PREPARED.

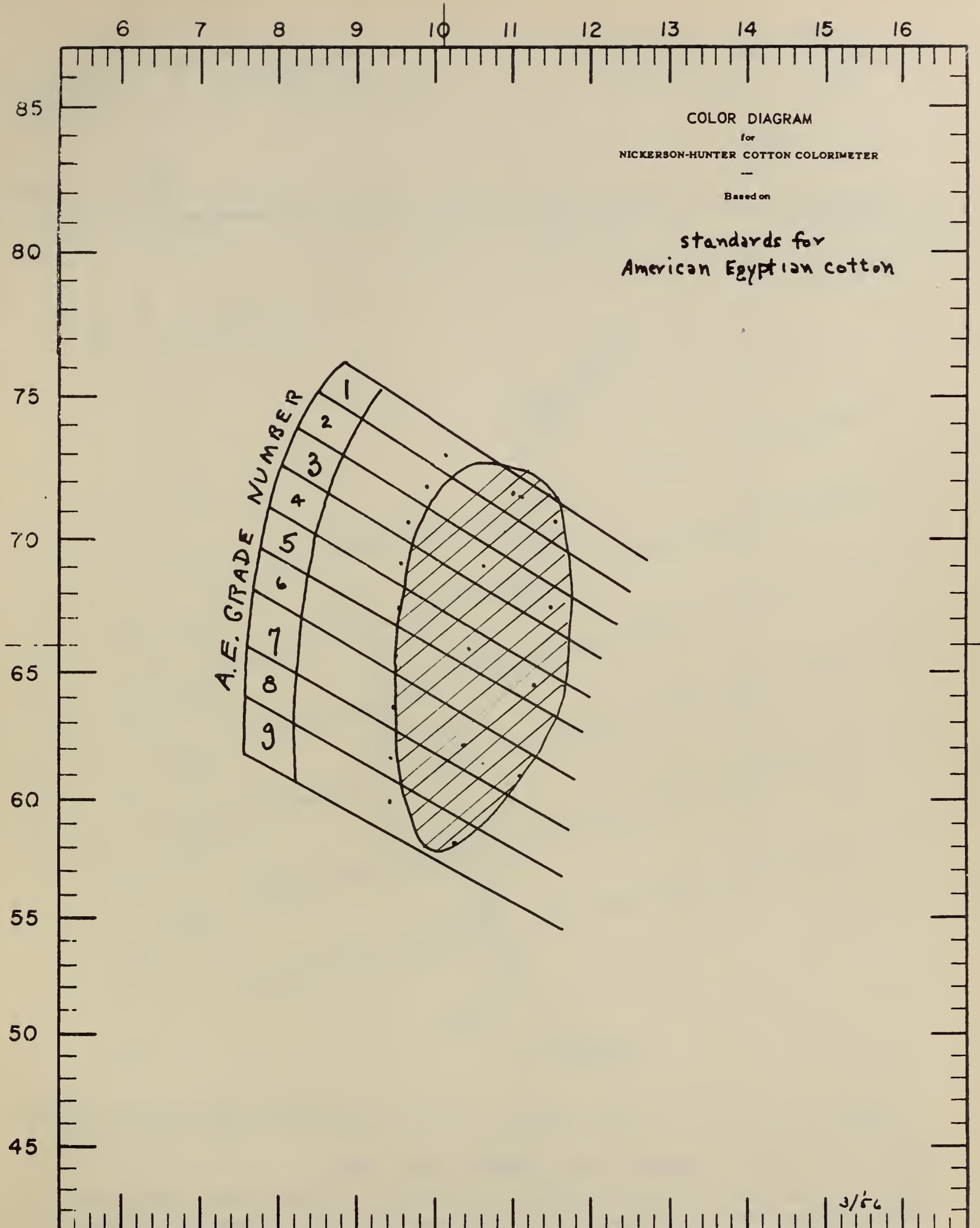


FIGURE 41.--RANGE OF COLOR OF AMERICAN EGYPTIAN COTTONS, GRADE SURVEY OF 1955 CROP SHOWN IN SHADED SECTION OF DIAGRAM.

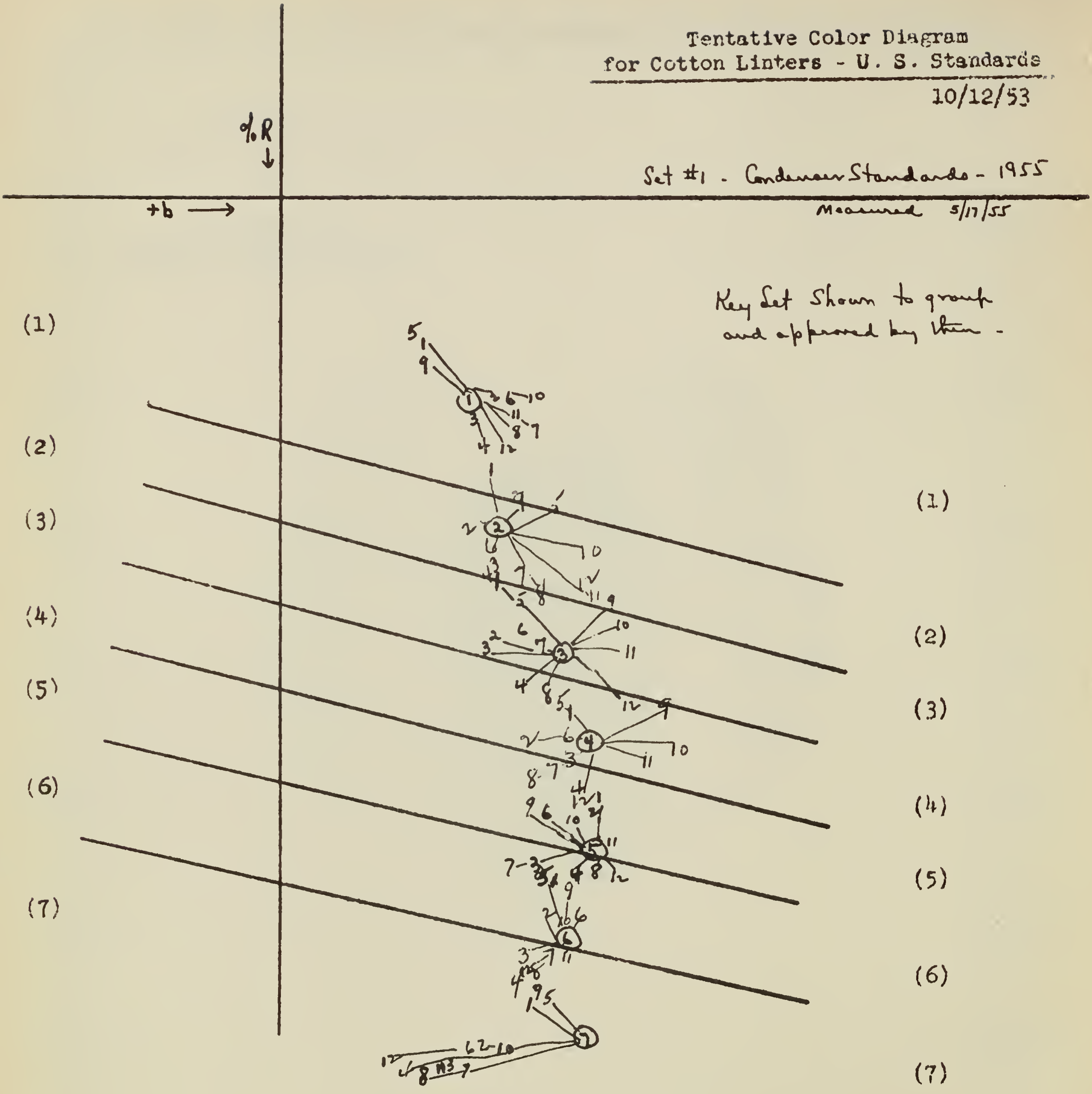


FIGURE 42.--LINTERS STANDARDS FOR CONDENSER TYPE LINT.

Key set shown May 1955 and accepted as guide for passing other 1955 sets. This diagram may be related to the level of the cotton standards diagram by use of the R_d and +b central crossbars. These are at R_d = 66.0, and +b = 10.1. The diagram is on the same scale as that used for the cotton standards.

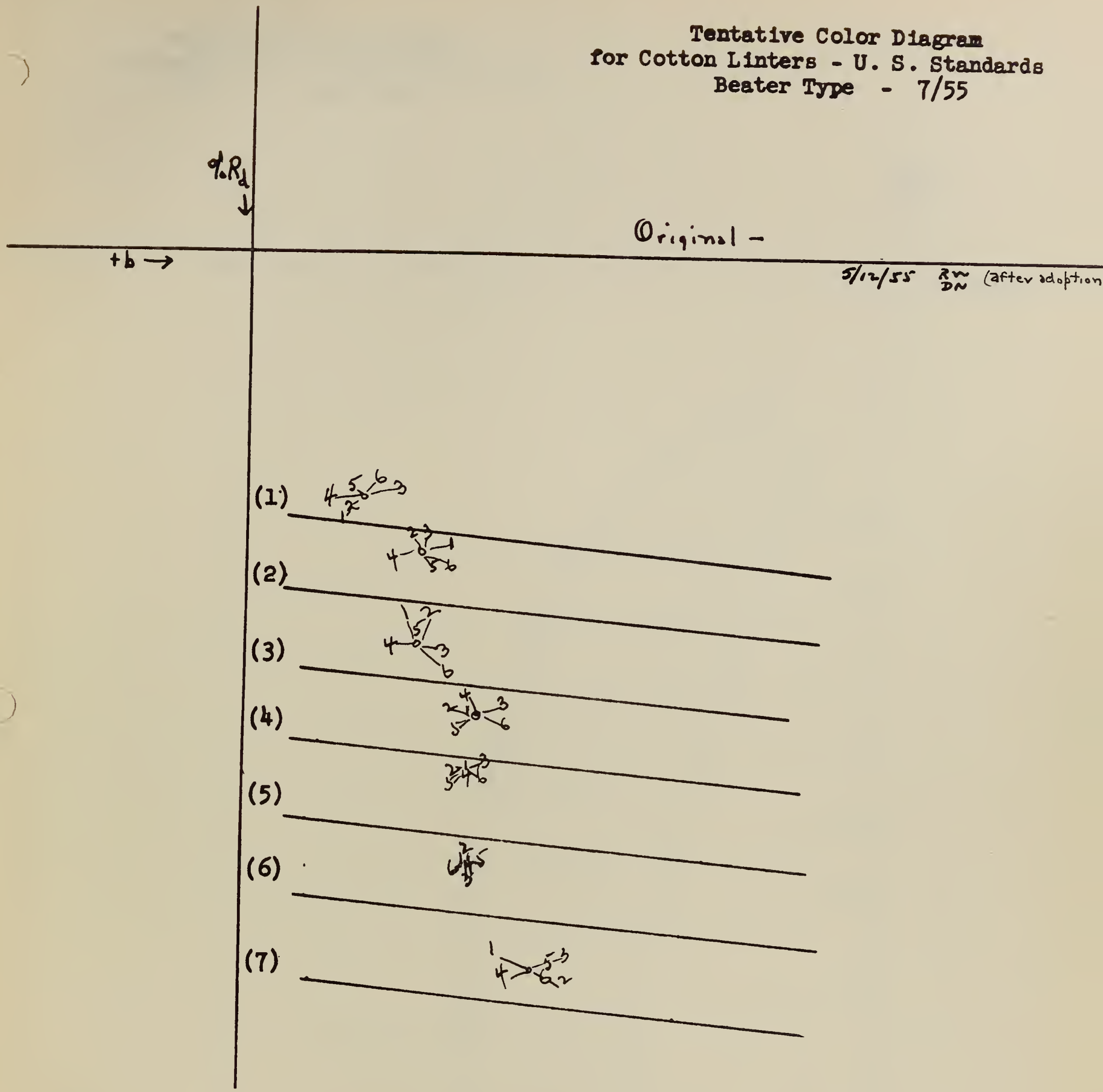


FIGURE 43.--LINTERS STANDARDS, COLOR OF ORIGINAL SET FOR FLUE TYPE LINTERS, ADOPTED MAY 1955.

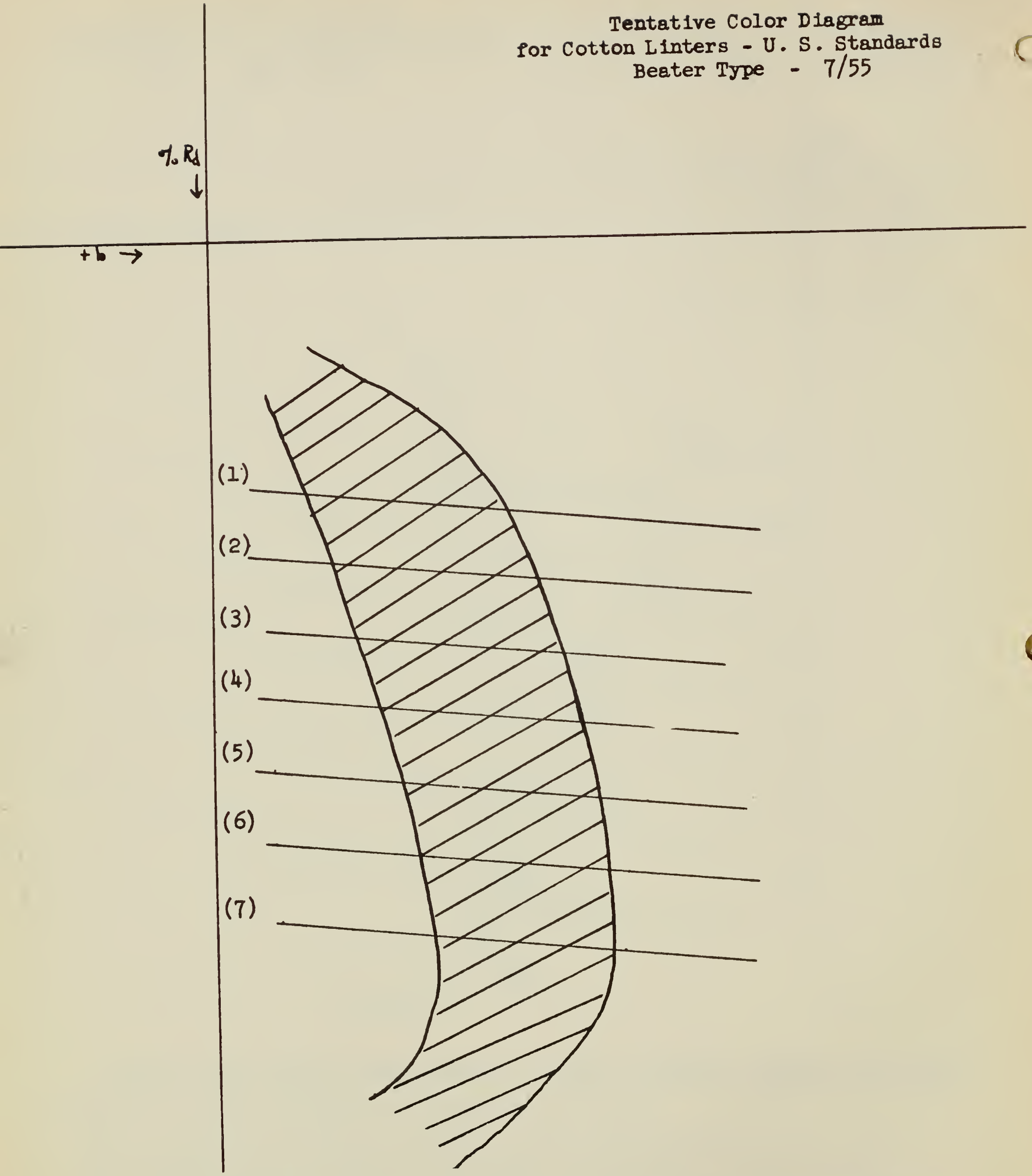


FIGURE 44.--LINTERS STANDARDS DIAGRAM SHOWING COLOR RANGE OF COTTON LINTERS.
Crop survey of 1954-55 shown in shaded area.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

GRADE STANDARDS: COLOR AND TRASH MEASUREMENTS

The attached five pages are from a report compiled May 1956 for the 11th International Cotton Grade Standards Conference: "COLOR MEASUREMENT DATA RELATING TO GRADE STANDARDS FOR COTTON AND COTTON LINTERS," (44 figures, 4 tables), by Dorothy Nickerson.

Each page contains information on a different phase of the cotton grade standards work, and together they provide a general summary of this work.

****

Washington, D. C.
October 1956

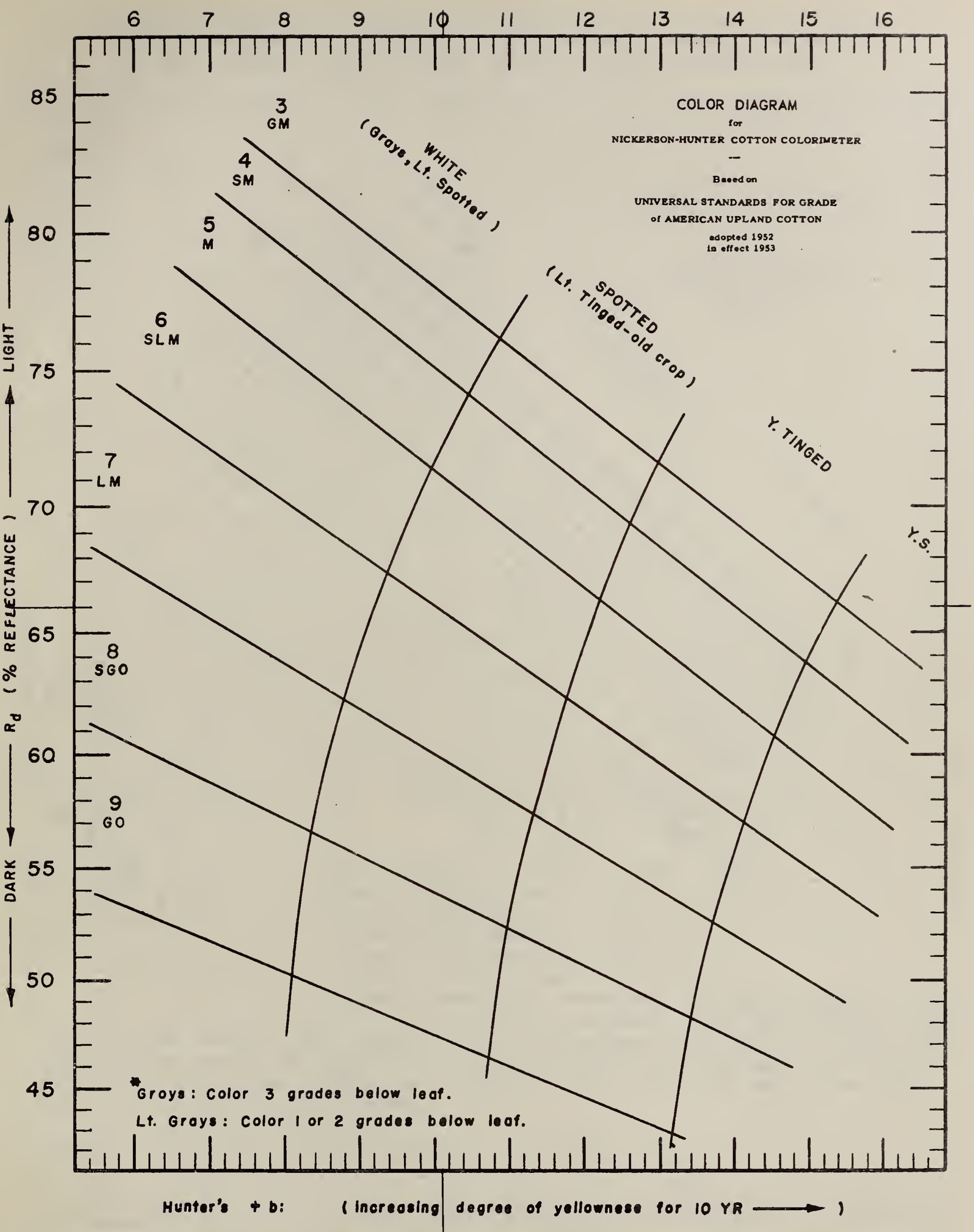
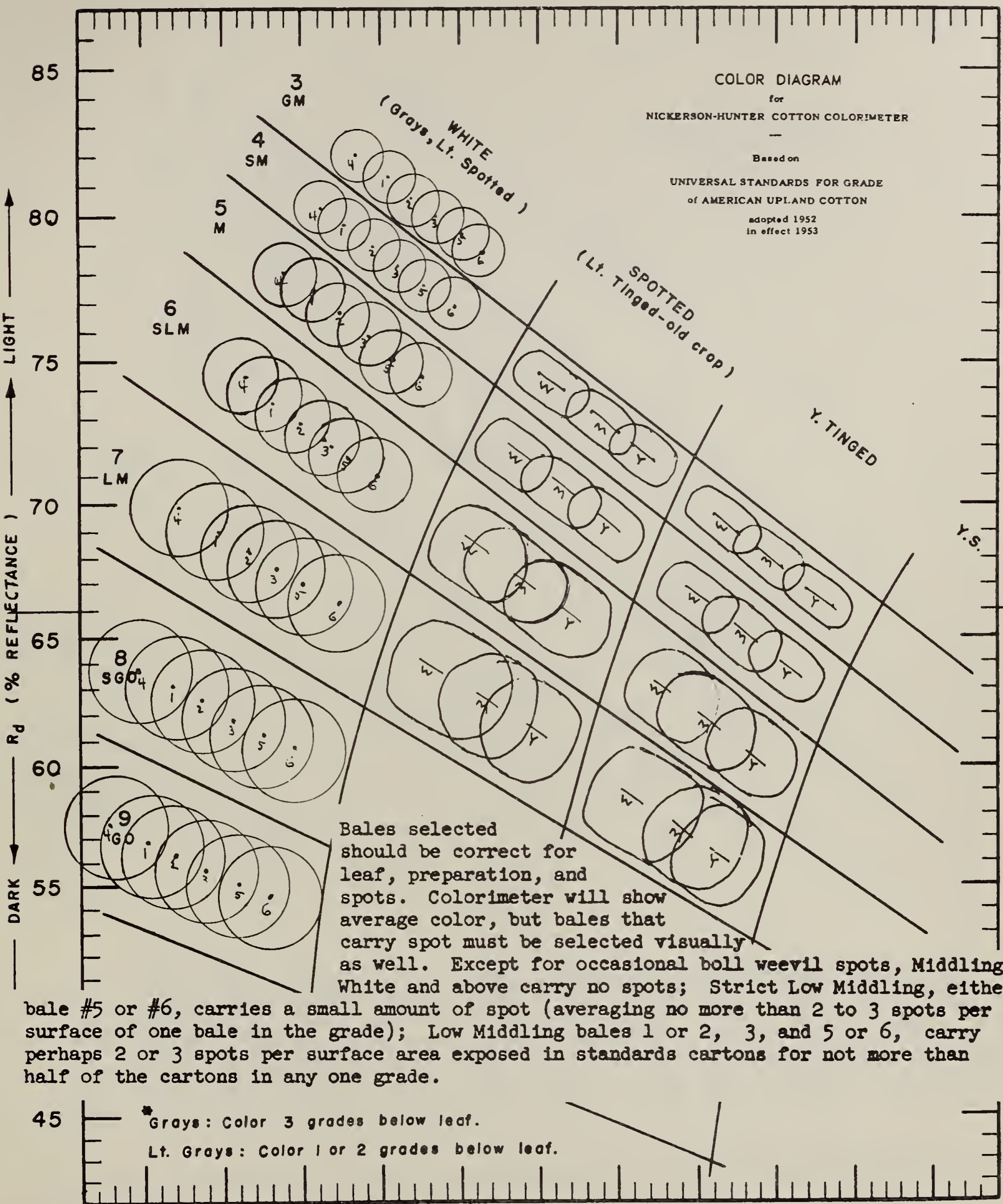


FIGURE 1.--COLOR DIAGRAM OF COTTON GRADES FOR THE NICKERSON-HUNTER COTTON COLORIMETER.

Color has three dimensions (hue, lightness, and chroma) but hue is so nearly constant for cotton that measurements of lightness and chroma are sufficient to define the color of cotton grades. Hunter scales used in this instrument are indicated in a vertical direction by percent reflectance (R_d), which measures the lightness of a sample, and in a horizontal direction by Hunter's +b which, for this instrument, indicates the degree of yellowness (with hue constant) and thus provides a measure of chroma. High grades are toward the top of the diagram, low grades toward the bottom; gray colors are toward the left, and tinged or stained colors toward the right The original of this diagram fits over the diagram on the instrument, so that indicated points may be plotted directly.

Guides for purchase of bales for standards. Dots (white grades) and short lines (spots and tinges) represent color positions wanted. Circles and ellipses indicate range of samples expected within purchased bales.

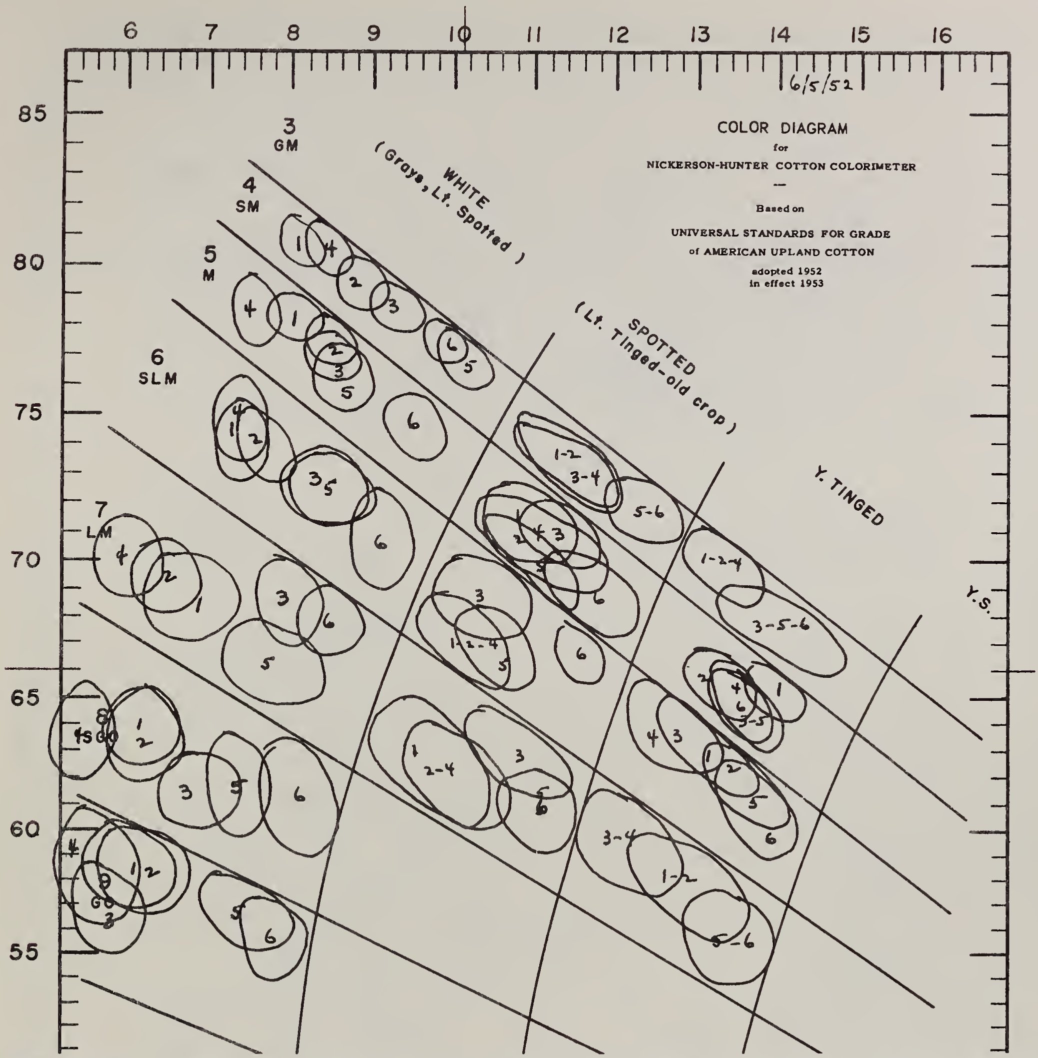


Bales selected should be correct for leaf, preparation, and spots. Colorimeter will show average color, but bales that carry spot must be selected visually as well. Except for occasional boll weevil spots, Middling White and above carry no spots; Strict Low Middling, either bale #5 or #6, carries a small amount of spot (averaging no more than 2 to 3 spots per surface of one bale in the grade); Low Middling bales 1 or 2, 3, and 5 or 6, carry perhaps 2 or 3 spots per surface area exposed in standards cartons for not more than half of the cartons in any one grade.

Bale positions 1,2 represent S.Central cottons; 3, Southeast; 4, West; 5,6,Southwest. For Spots and Tinges three colors W(hite), M(edium); and Y(ellow) are required.

FIGURE 2.--COLOR GUIDE FOR PURCHASE OF BALES FOR COTTON GRADE STANDARDS.

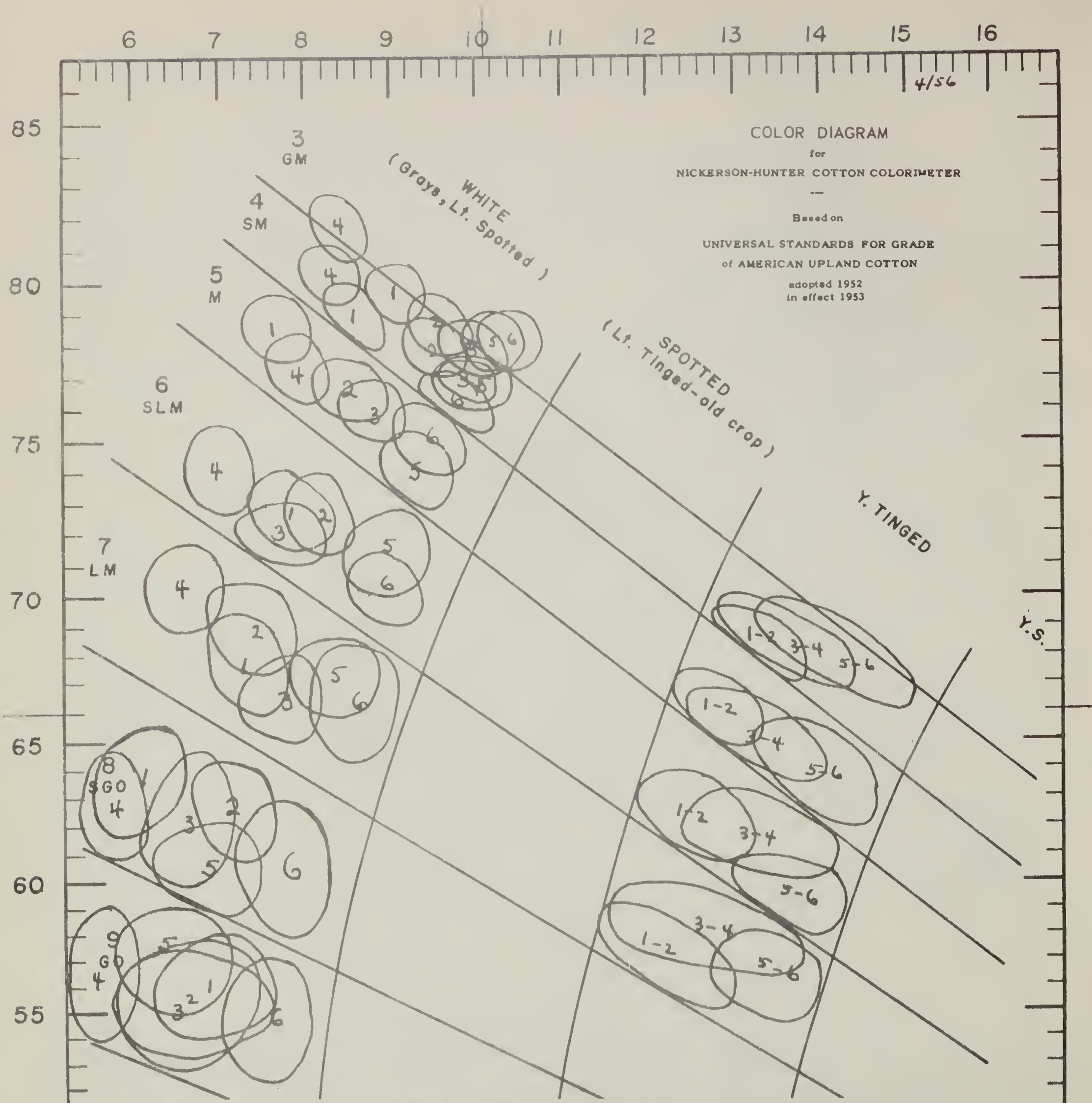
This guide is based on standards adopted in 1953 that were, in turn, based on crop survey data available for many years. Color for positions in White grades is based on the relation of the average grade color for cottons grown and classed in four cotton areas over a period of many years.



	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	129245	876309	68328	136293	136004	695464	367656	753450	250517	32374	380046	2639716	13427	11667
2	146897	149430	1084395	879593	136005	695564	367565	499916	250517	2771	380046	13173	13427	11667
3	15294	17534	8449922	825	372322	1350315	677816	677808	179735	759793	713627	13155	17417	18218
4	588016	564143	405229	1667914	7797614	608667	677816	751034	250517	2771	380046	259743	24078	18218
5	266981	178953	2644949	22838	2446522	13121	542617	261428	10891	28941	713627	13155	269415	11824
6	110856	266843	31601	2629166	13115	13155	542617	2657539	24078	11642	713627	13173	13369	11824

FIGURE 8.--BALES PURCHASED ON BASIS OF FIGURE 2 THAT WERE USED IN PREPARING GRADE STANDARDS ADOPTED IN 1952.

The Original Set, #101, was selected from boxes put up from these bales.



	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	19642	19567	19652	19478	19522	19673	19262	19690	19495	19390	19705
2	19566	19569	19606	19520	19481	19482	19261				
3	19595	19592	19587	19455	19349	19218	19352	19525	19658	19447	19692
4	19588	19573	19600	19636	19505	19670	19693				
5	19544	19580	19563	19511	19496	18153	19698	19700	19291	19490	19278
6	19542	19582	19564	19612	19127	18151	19703				

FIGURE 36.--RANGE OF COLOR IN 12-SAMPLE STANDARDS BOXES PUT UP FOR THE 1956 UNIVERSAL GRADE STANDARDS CONFERENCE.

These measurements were made on 110 sets of large boxes after they were put up for the conference.

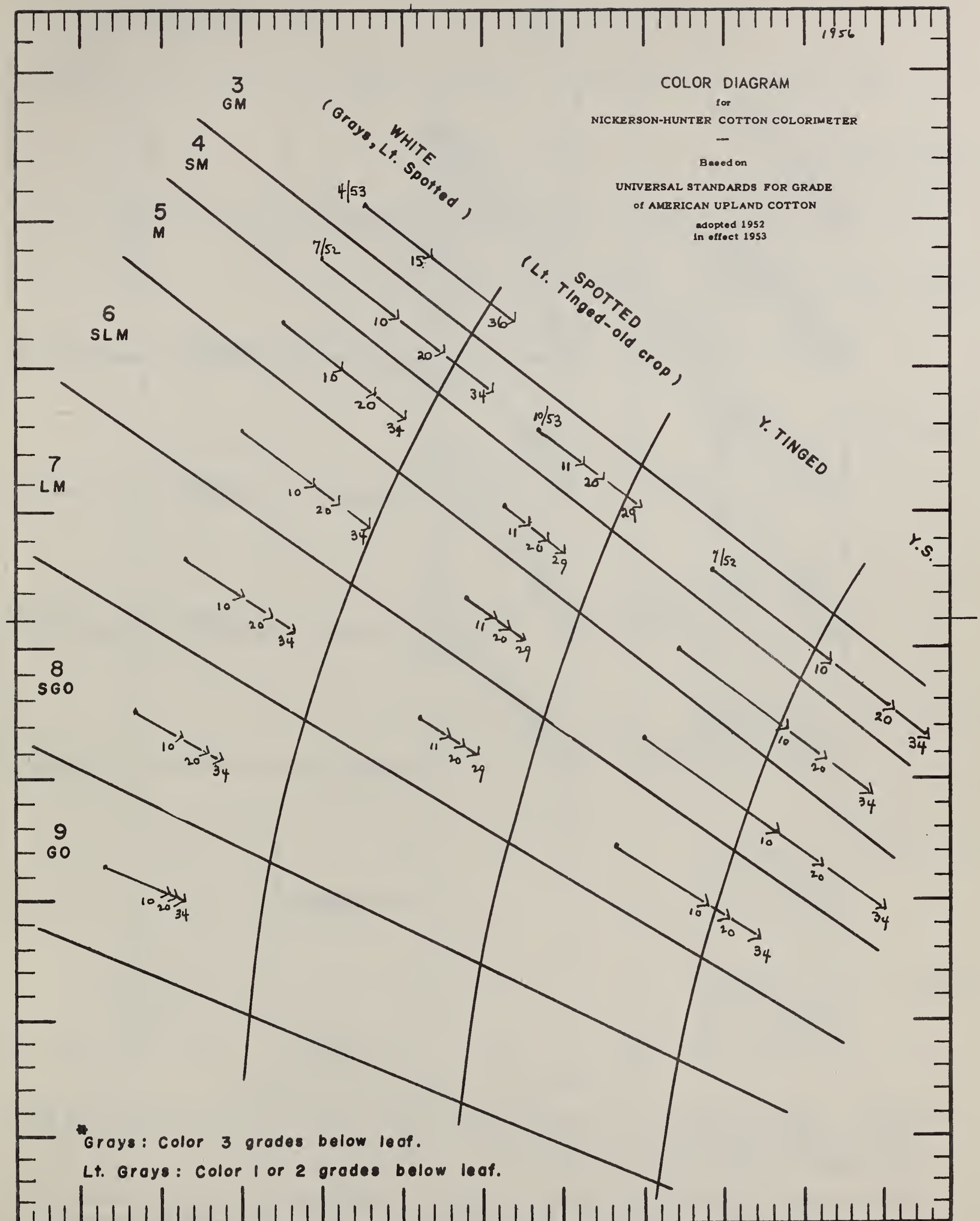


FIGURE 23.--AVERAGE COLOR CHANGE IN STORAGE FOR ORIGINAL STANDARDS AND GUIDES: 36 MONTHS FOR GM WHITE, 34 MONTHS FOR SM TO GO WHITE AND SM TO LM TINGE, 29 MONTHS FOR SPOTTED. The number of months between measurements is indicated below each arrow.

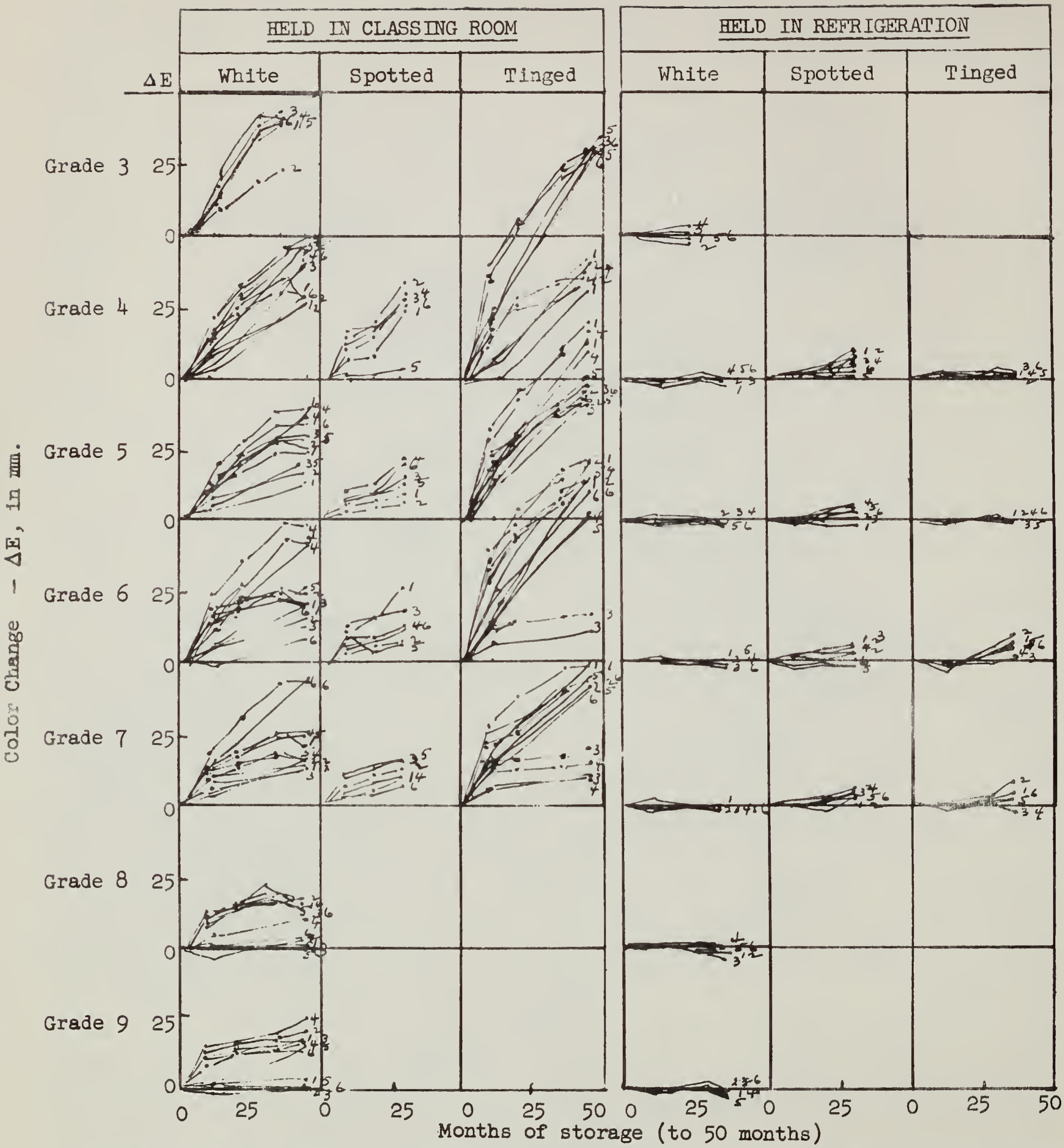


FIGURE 25.--COLOR CHANGE, ΔE, BY MONTHS OF STORAGE, INDICATED FOR EACH BALE IN WHITE, SPOTTED, AND TINGED GRADES HELD IN WASHINGTON UNDER CLASSING ROOM CONDITIONS, AND UNDER REFRIGERATION AT ABOUT 38°.

Refrigeration either slows down, or inhibits, color change. A controlled experiment, under several conditions of humidity and temperature, will be carried out 1956-1959 on cottons accepted at 1956 conference, so that by 1959 it should be possible to specify optimum conditions for temperature and humidity control for storing cotton standards. These are not now known.

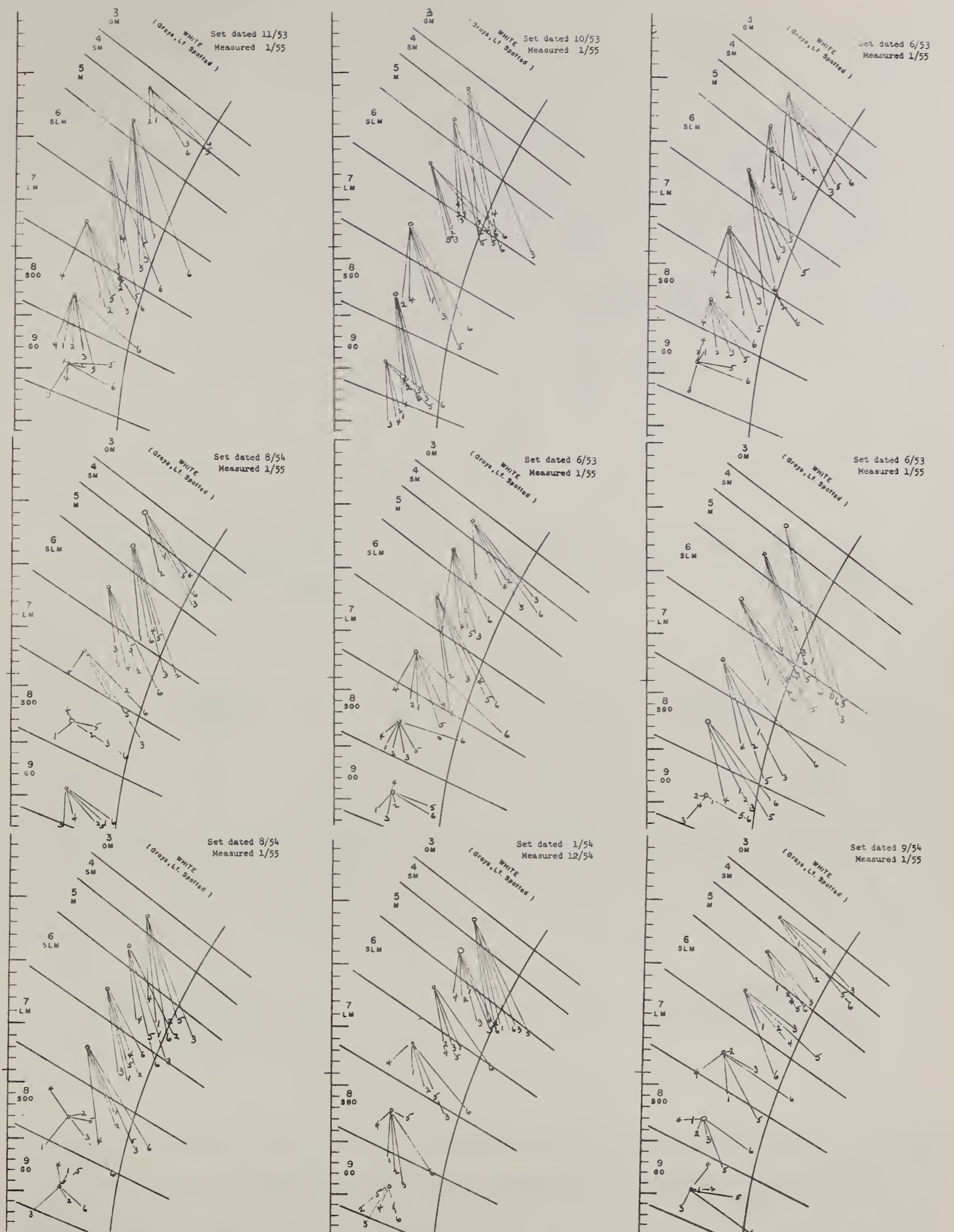
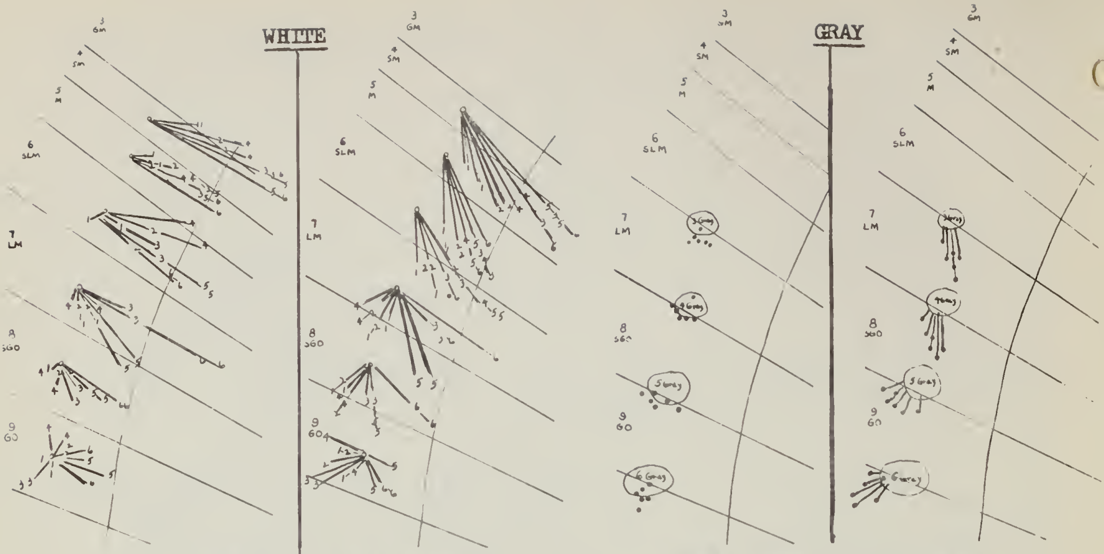


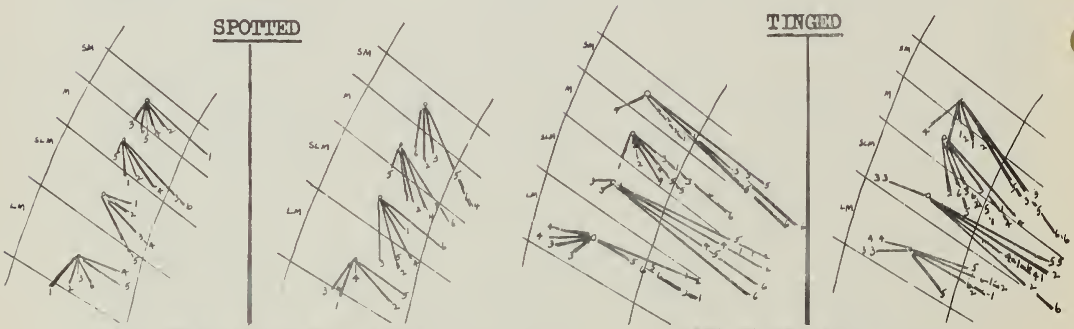
FIGURE 28.--MEASUREMENTS ON SETS OF STANDARDS TYPICAL OF THOSE RETURNED AFTER USE.

Each set shown is from a different office, with each classing area represented. A study in 1955 of returned standards shows that this amount of color change through dustiness, from being open in a classing room while in use, is not uncommon for standards used a great deal. This change, so easily overlooked, even by experienced classers, is another good reason why standards should not be used more than one season, sometimes no longer than one month. None of these boxes were more than 18 months old when returned for study. The dates of issue and of measurement after return are shown for each set.



Left shows aging and careful use; right shows aging and hard use.

Left shows little change with aging; right shows change through use.



Left shows aging and careful use; right shows aging and hard use.

Left shows aging; right shows aging, and use of two top grades.

FIGURE 30.--MEASUREMENTS ON RETURNED STANDARDS, AFTER USE OF 18 MONTHS OR LESS.

Sets are shown in pairs to illustrate two types of change, yellowing by aging, and darkening by dustiness caused by use of standards.

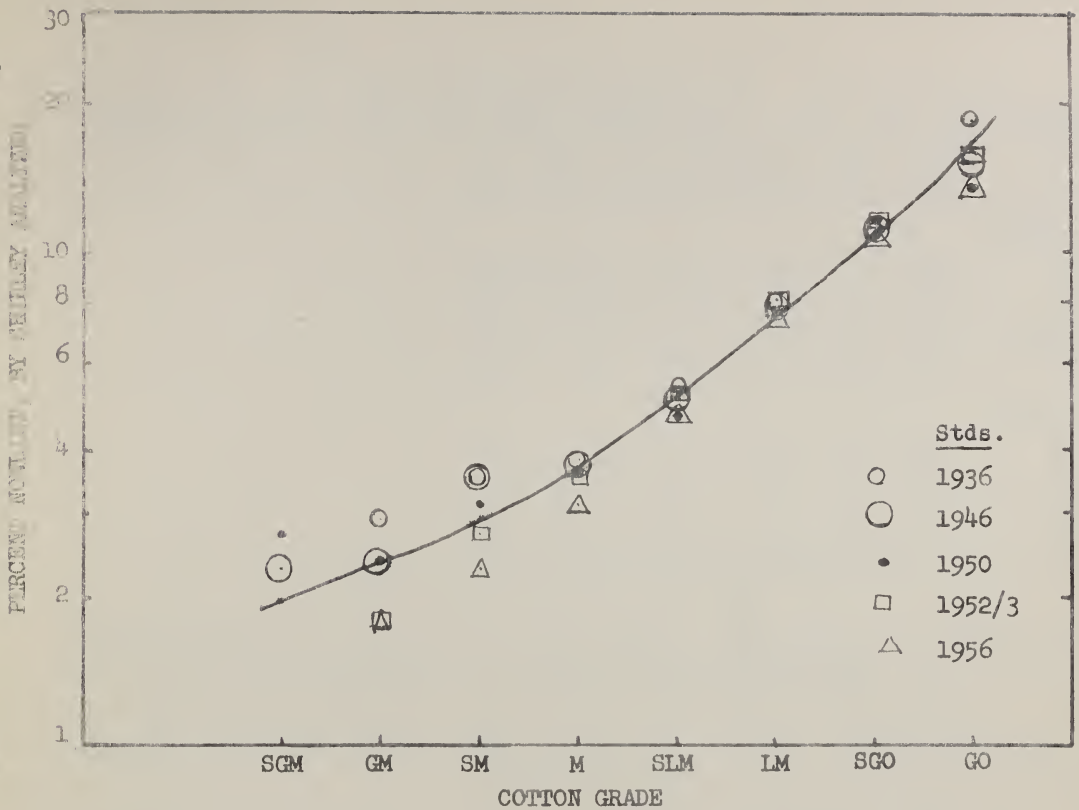


FIGURE 32.--TRASH ANALYSIS FOR BALES USED IN STANDARDS, 1936-1956.
See Note following table 4 for discussion and explanation.

THIS PAGE FOLLOWS FIGURE 34

Table 3.--Shirley Analyzer trash in grade standards bales, 1936, 1946, 1950, 1952/53, and 1956, and in grade surveys 1947, 1950, 1951, 1952, and 1953.

Year	GM	SM	M	SLM	LM	SGO	GO
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Stds. bales							
1936	2.9	3.6	3.8	5.4	8.1	11.0	18.6
1946	2.4	3.5	3.7	5.1	7.7	11.2	15.2
1950	2.4	3.1	3.6	4.7	7.6	11.7	13.5
1952/53	1.8	2.7	3.5	5.2	8.1	11.5	15.3
1956	1.8	2.3	3.1	4.7	7.3	10.7	13.3
Grade Survey							
1947	3.5	4.0	4.6	5.5	7.8	11.0	15.3
1950	1.8	2.7	3.5	5.1	7.2	11.4	15.4
1951	2.2	2.3	3.2	4.3	6.5	9.8	13.5
1952	2.2	2.3	3.3	4.8	6.8	9.6	12.1
1953	2.1	2.5	3.2	4.6	6.7	10.2	13.4

Table 4.--Shirley Analyzer trash for top and bottom of bales in 1956 standards.

Bale position	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Std.	2.4	2.9	3.7	5.1	7.6	11.0	17.0				
1	1.6	2.5	3.4	5.0	6.6	10.0	13.5	3.6	7.6	10.1	6.4
	1.6	2.2	2.8	4.2	6.8	10.9	13.3	3.9	6.3	11.9	6.2
2	2.2	2.3	2.7	4.7	6.5	11.6	12.2				
	2.8	2.0	3.0	5.0	6.7	10.9	12.8				
3	1.7	1.9	2.5	5.1	8.7	11.2	13.3	4.1	4.8	8.6	10.8
	1.2	1.7	2.3	5.6	7.8	11.1	11.2	4.2	4.2	10.3	11.0
4	2.1	2.3	4.0	5.8	8.4	10.0	12.2				
	2.2	3.0	4.0	5.0	8.7	9.1	12.3				
5	1.7	3.0	3.4	4.8	6.9	8.7	16.4	3.1	3.8	8.6	8.7
	1.7	2.8	3.0	4.1	7.1	8.7	17.7	2.9	4.0	7.4	8.7
6	1.3	2.0	3.3	3.5	7.3	14.2	12.7				
	1.6	1.9	3.0	3.5	6.3	11.8	12.5				
Average	1.8	2.3	3.1	4.7	7.3	10.7	13.3	3.6	5.1	9.5	8.6

NOTE: Compared to the average of past standards, bales for practically all 1956 grades are lighter in trash than intended when bales were purchased. Trash has had to be added to some boxes, but this has been kept to a minimum in order to hold to the principle of a natural standard.

Trash studies during the next three years (more intensive with a new Cotton Trash Meter) should provide information for judging whether current cleaning methods at the gin are resulting in so much less trash that adjustments need be made in standards.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

GRADE AND COLOR INDEXES DEVELOPED FOR EVALUATING RESULTS OF USDA COTTON FINISHING TESTS

By Dorothy Nickerson, Cotton Technologist
and Franklin E. Newton, Cotton Technologist

AMS--245 Washington 25, D. C. June 1958

GRADE AND COLOR INDEXES DEVELOPED FOR EVALUATING RESULTS OF USDA COTTON FINISHING TESTS

By Dorothy Nickerson, Cotton Technologist
and Franklin E. Newton, Cotton Technologist

Three years of chemical finishing data are now available on the Annual Quality Studies (1), (2), (3), (4) published by the Cotton Division of the Agricultural Marketing Service, U. S. Department of Agriculture, and an analysis of these data is needed for making an evaluation that will relate the results both to the cotton standards and to significant cotton quality factors that have been measured for the cottons tested.

Color of the bleached and dyed yarns related to color of the raw stock and/or grey yarns used in processing provide one direct basis for quality evaluation of these finishing tests. Uniformity of color processing is also important, but these first studies are confined to yarn color evaluation.

Color measurements made in the laboratories of the Cotton Division are in terms of the R_d and b scales of Hunter's colorimeters. Raw cotton is measured on the Nickerson-Hunter Cotton Colorimeter, an automatic, self-standardizing electronic instrument that converts color directly to terms of equivalent grade (figure 1). Yarns, in skein form, are measured on a Gardner Automatic Color-Difference Meter equipped with a specially designed turret top and clamp for holding yarn samples.

There are three scales on the Color-Difference Meter, R_d, a, and b. The R_d scale measures percentage of reflectance from 0 to 100. The b scale provides a measure of yellowness in the direction of +b (as in raw cotton, or grey or bleached yarns) and of blueness in the direction of -b (as in the blue-dyed cotton yarns of the standardized dyeing test), the degree of yellowness or blueness increasing as the scale numbers increase. In effect, the b measurements are used in the cotton work as an indication of saturation. The a scale provides a measure of redness in the direction of +a and greenness in the direction of -a. Since the inclusion of this factor would simply help to indicate hue, which usually remains quite constant in the studies being reported, results for the a scale are not included. If in dyeing tests another color than blue were used, then it might be necessary to report the a factor instead of, or in addition to, the b factor. The color data are directly indicated on the Cotton Colorimeter in terms of a two-dimensional plot of R_d (vertical) against b (horizontal).

Since color has more than one dimension it does not lend itself directly to any simple one-dimensional statistical treatment. In order to use color as a single, or a dependent, variable in statistical analyses it would be very convenient if the two- or three-dimensional color results could be reduced to a set of related indexes, each one a single-number expression for the color, or for the color differences, between the samples used in each of the forms studied (raw stock, grey, bleached, and dyed yarns).

A parallel problem exists in expressing the grade of cotton in a single number. Grade is not a one-dimensional series; it is two-dimensional, for there are high to low grades that may be Gray, White, Spotted, Tinged, or Yellow Stained. Some years ago a common denominator was worked out for the grades in these several color classifications in order that an "average grade" might be calculated, also that grade might be used as a dependent variable in statistical analyses of its relation and dependence on measurable cotton quality characteristics. To make such studies a single-number index was needed, and as a result, the grade index in table 1 was developed. With Middling arbitrarily set at 100, the relative grade relations, whether based

Table 1.--Grade names, symbols, code numbers and index values

Color class	Grade name	Symbols	Code	Grade Index
White * (2)	Good Middling	GM	3 *	105
	Strict Middling	SM	4 *	104
	Middling	M	5 *	100
	Strict Low Middling	SLM	6 *	94
	Low Middling	LM	7 *	85
	Strict Good Ordinary	SGO	8 *	76
	Good Ordinary	GO	9 *	70
Spotted (3)	Good Middling Spotted	GM Sp	33	101
	Strict Middling Spotted	SM Sp	43	99
	Middling Spotted	M Sp	53	93
	Strict Low Middling Spotted	SLM Sp	63	83
	Low Middling Spotted	LM Sp	73	75
Tinged (4)	Good Middling Tinged	GM Tg	34	94
	Strict Middling Tinged	SM Tg	44	91
	Middling Tinged	M Tg	54	82
	Strict Low Middling Tinged	SLM Tg	64	75
	Low Middling Tinged	LM Tg	74	68

* The code (2) for color class which follows the grade number code, is sometimes omitted in reporting the White grades, e.g. either (3) or (32) for GM White. The superscripts used to further identify bales in figures 3 to 6 refer to bale positions 1 to 6 in the White grade boxes, and the letters in the Spotted and Tinged grades refer to bales intended to represent white (W), middle (M) and yellow (Y) color within each grade.

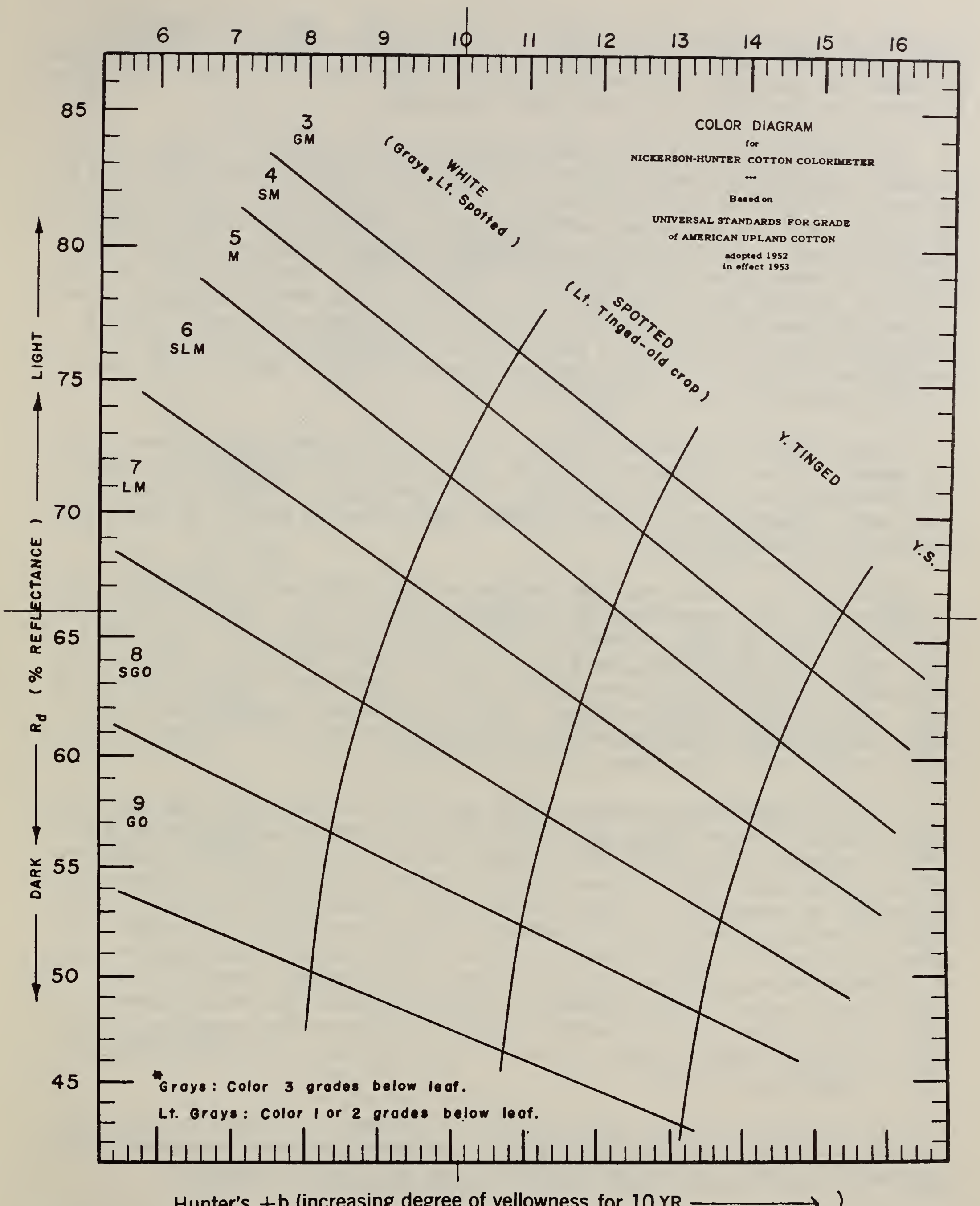


Figure 1.--COLOR DIAGRAM FOR NICKERSON-HUNTER COTTON COLORIMETER illustrating the relationship between color measurements (R_d and b) and equivalent grade color (in terms of the Universal Standards for Grade of American Upland Cotton).

on price 1/ or on color, were found to be as given. When the numbers in table 1 for each grade are entered on the diagram in figure 2 it is possible to check the closeness with which the grade index represents the color relationships in the official cotton grade standards.

This conversion from color measurements of raw stock to a grade index provides a straightforward method of obtaining a single number index for raw cotton. It does not allow full use of the two-dimensional relationships of the grades, and may sometimes even mask their relationships with certain quality factors. However, it does provide a means for making preliminary studies in terms of a one-dimensional scale, studies that later can be extended to include the two-dimensional variations. A similar method has been followed in developing conversion formulas and diagrams for each form of cotton measured for color as a part of the chemical finishing studies of the Cotton Division. In each the index for Middling is held at 100 and that for Good Ordinary is held close to 70.

Color data are shown in figures 3 to 6 for four sets of samples, each set based on results from 55 bales of cotton selected to cover the gamut of the American Upland grade standards. These are in the form of raw stock, grey yarns, bleached yarns, and bleached and blue-dyed yarns, all made from the same series of cottons.

The spread of color for the samples of raw stock and of the grey yarn is wide. The color spread in the bleached yarns is less, and in the dyed form the spread of color begins to fit a single straight line. In order that each set of data shall be treated in the same way, a line of best fit was found by the least squares method and a correlation computed for the R_d and b relationship within each set. The correlation, expressed as r, is shown for each set with its accompanying standard error in figures 3 to 6. The line of best fit is drawn in on each diagram.

The two-dimensional scatter of R_d and b in the raw stock and grey yarns (which makes it possible to differentiate White, Spotted, and Tinged grades as well as grades Good Middling through Good Ordinary) precludes the possibility of any high degree of correlation between the R_d and b color factors. Therefore, as expected, no significant single straight line correlation was found to exist between R_d and b either for raw stock or for grey yarn color. While it might be expected that bleaching would reduce all 55 samples close to a single color and thus provide a closer correlation between R_d and b for the bleached yarns, it was found that after bleaching the color spread still bears considerable relation to the spread of color in the raw stock and in the grey yarn. When it comes to the dyed yarns (dyed after bleaching) the

---

1/ Based on average annual prices on designated markets for the various grades during the years 1937-38-39, but showing also a remarkably close agreement to the color relationships of the 1953 grade standards.

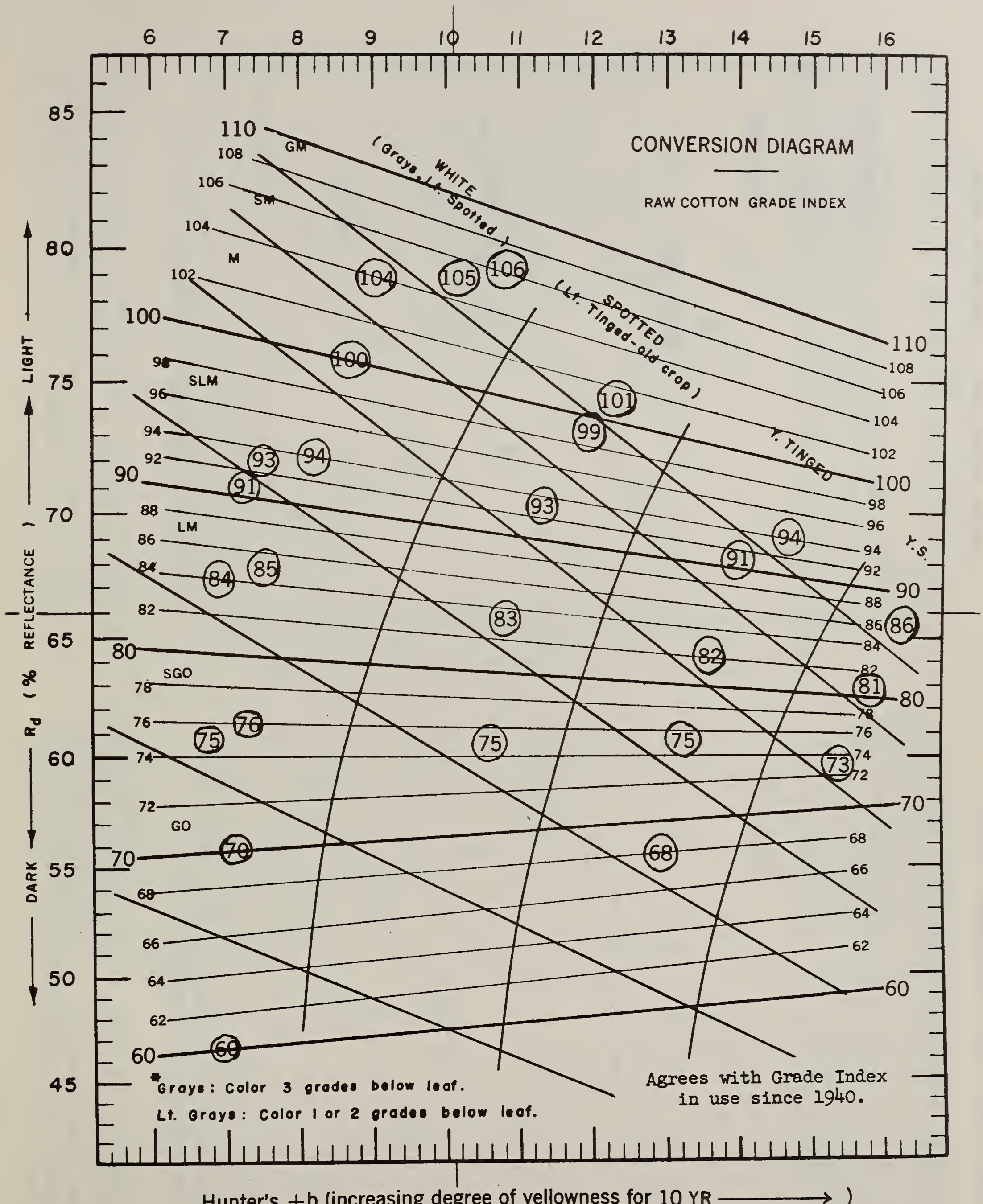


FIGURE 2.--LINES OF EQUAL GRADE INDEX AGAINST A COLOR DIAGRAM OF THE COTTON GRADE STANDARDS. The circled numbers represent index values from table 1 plotted within the color blocks of appropriate grades. Except for the Gray grades, these index numbers fall well within the color limits of appropriate grades (many close to the center of the grade). This diagram indicates the closeness with which the grade index (based on price) relates to the color of the official cotton grade standards.

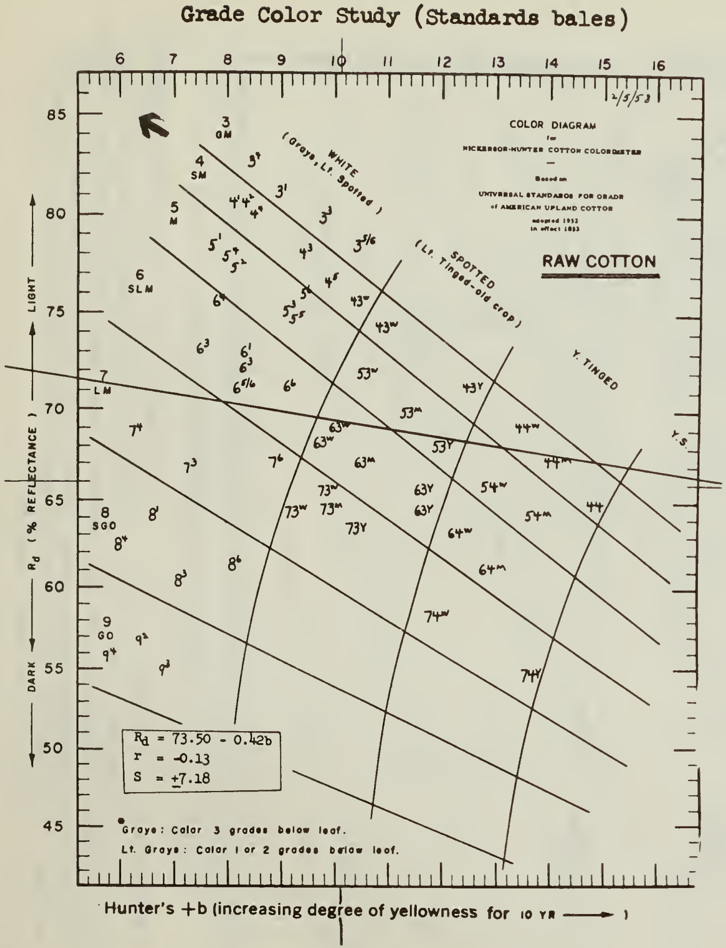


Figure 3.--Color of 55 bales of raw cotton, GM to GO and White to Yellow Tinged. The scatter of samples is so great that there is no significant fit to a single line. The heavy arrow points in the direction of White. Identifying numbers refer to the grade code in table 1.

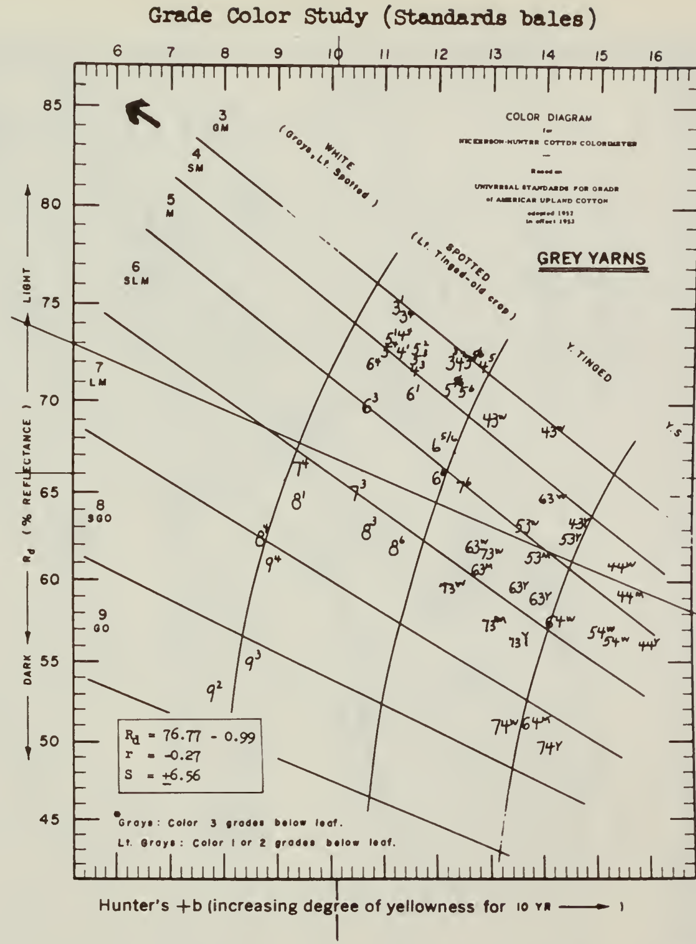


Figure 4.--Color of 22s yarns made from the cottons shown in figure 3. Yarn color shifts toward yellow, and colors are more compressed for high than for low grades. The heavy arrow points in the direction of White.

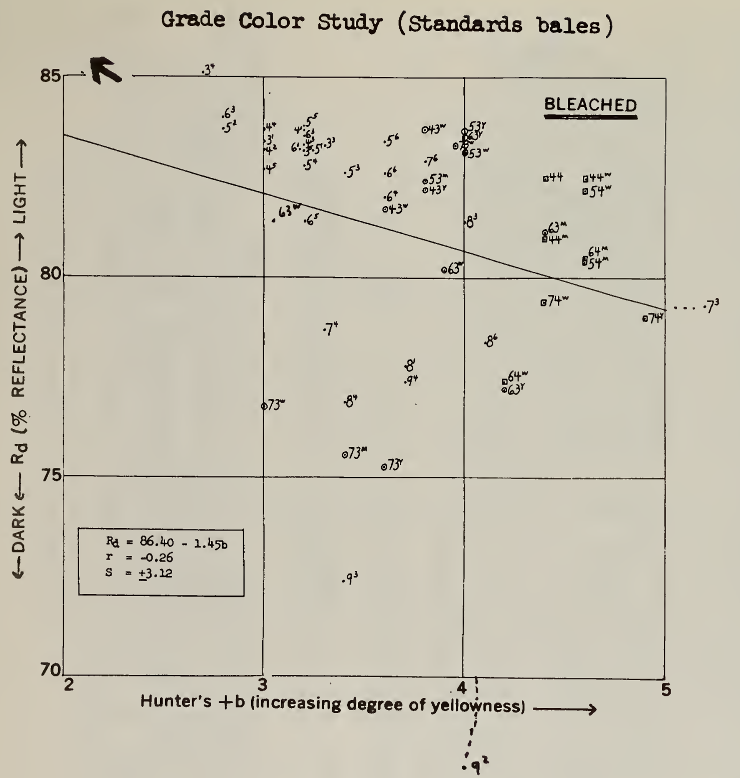


Figure 5.--Color of bleached 22s yarns made from the cottons shown in figure 3. The color has shifted toward White. In general, the higher grade cottons have bleached to a higher reflectance than the lower grades, and Spotted and Tinged cottons have retained more yellow than the White cottons. The heavy arrow points in the direction of White.

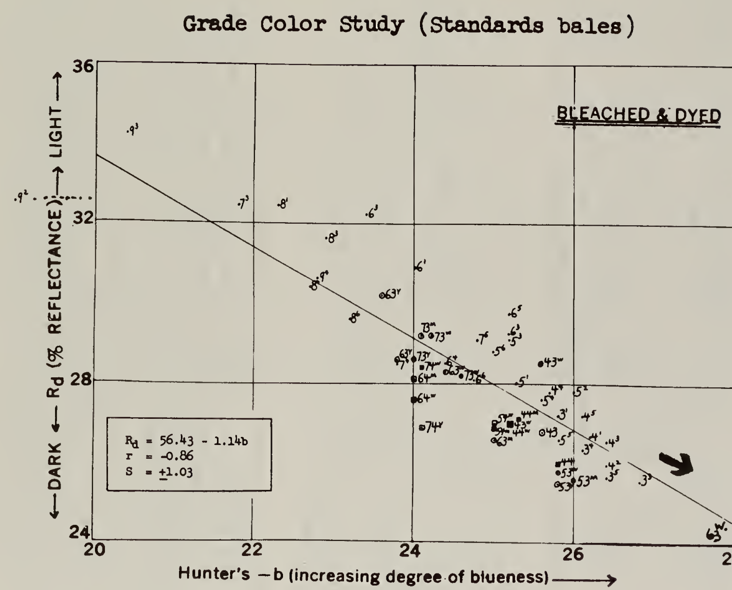


Figure 6.--Color of bleached and blue-dyed 22s yarns made from the cottons shown in figure 3. With few exceptions the high grades have dyed the deepest blue. The heavy arrow points toward a saturated blue.

color spread is reduced enough so that a significant correlation of R_d and b is found around a line of best fit. It is important to keep in mind the fact that the data for each form of yarn studied are based on the same raw stock, and that while there is a better approach in the dyed yarns to a single line fit it is only because the color relations are more compressed than in the raw stock. The data are shown in the same manner for all four sets in order that their relation, and their dependence on each other, may be kept in mind. Numbers used to identify samples in the plotted diagrams are code numbers for the grades.

The grade index of table 1 is shown in figure 2 with lines of constant index number drawn in on the diagram. While these lines are straight they are not parallel, therefore it is easier to obtain the grade index for raw stock directly from a conversion diagram of this sort than to try to find a formula to convert the R_d and b color measurements to an index. Use the diagram in figure 7 to convert R_d and b color measurements of raw stock to the grade index for raw cotton.

To convert color measurements to a grey yarn grade index use the diagram in figure 8. On it a grade diagram is indicated for grey yarns, based on the color data in figure 4. In preparing this diagram the grade index figures of table 1 were entered in the appropriate spaces on the grade diagram, 100 in the center of the Middling block, 94 in the center of Strict Low Middling, 70 at Good Ordinary, with index numbers representing the Spotted and Tinged grades entered in their respective grade spaces. Lines for equal index numbers were then drawn in by the method used in preparing figures 2 and 7. Because these lines of equal index number are straight but not parallel, it is easier to obtain the grey yarn index by use of figure 8 than by use of a formula.

In preparing a diagram (figure 9) for converting color measurements of bleached yarn to a grade index, a somewhat different procedure was used. Since it was no longer clearly evident just how the grade lines should be drawn in, a calculation was made of the average amount of change in R_d and b in the bleached yarn as related to changes in grey yarn color. In bleached yarns each unit change of +b (grey yarn) makes 1.7 more change than a unit change of R_d. This relation was used—holding the level and spread of index values for bleached cottons to 100 for Middling and close to 70 for Good Ordinary—to develop the following formula:

$$\text{Bleached Yarn Grade Index} = 4\left(-20.7 + \frac{R_d}{1.7} - b\right)$$

when: R_d = reflectance of bleached yarn (22s)
b = +b, yellowness of bleached yarn (22s)

The constant (-20.7) places Middling at 100, and the constant (4) spreads the indexes so that Good Ordinary is close to 70. Use figure 9 (or this formula) to obtain the grade index for bleached yarns from R_d and b color measurements. Lines of constant index number are centered on the line that best fits the data in figure 5. To help understand something about the grade relationships involved, the data of figure 5 should be thought of in relation

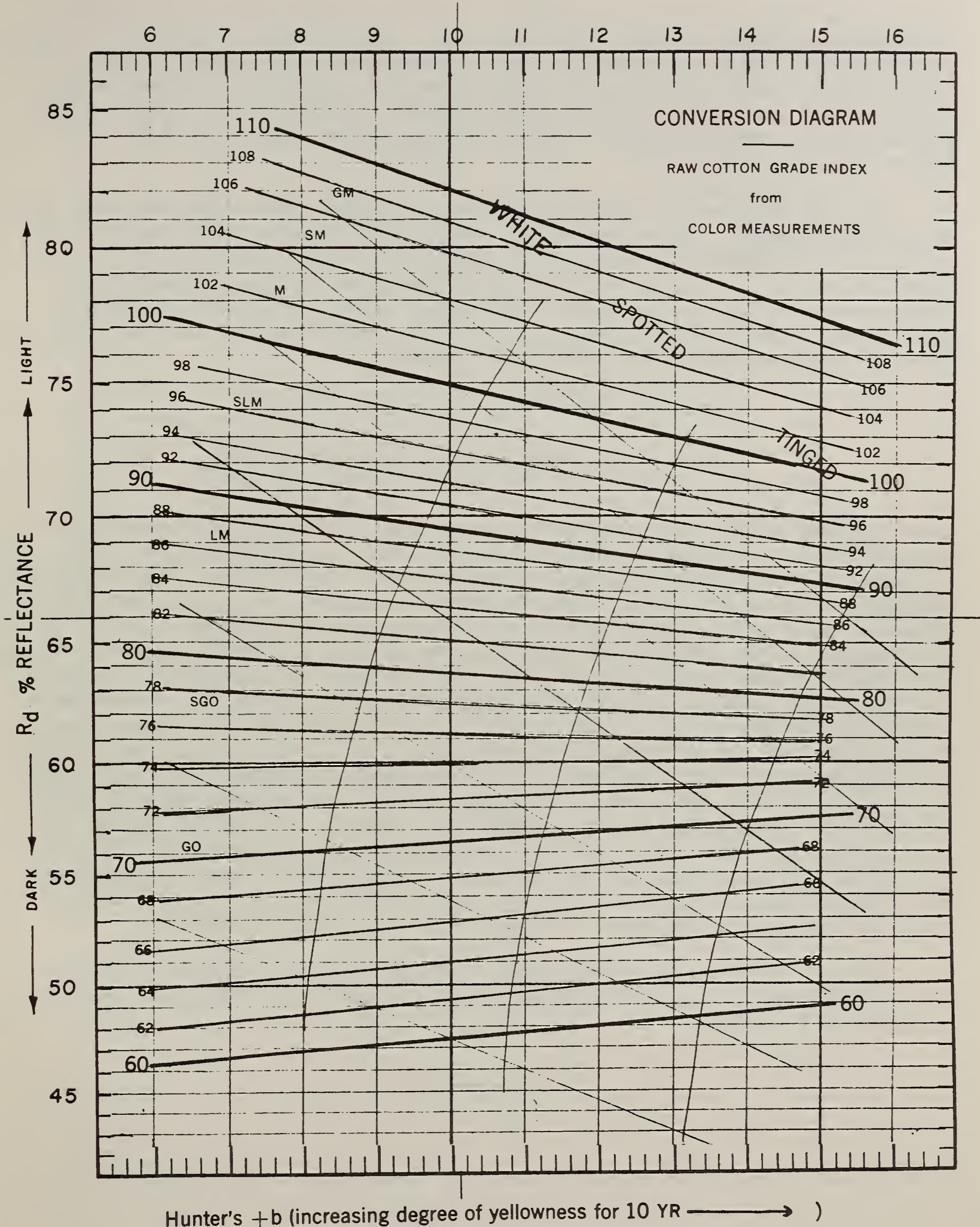


Figure 7.--Diagram for Converting R_d and b measurements of Raw Cotton to a Raw Cotton Grade Index, 60 through 110.

to the conversion diagram of figure 9, for it is upon these data that the conversion diagram is based. At this point in our studies there is no clear way to adjust for the apparently closer relationship that exists between the results for Tinged grades than for White grades, therefore lines of equal index number are left parallel on the diagram, although from a look at the spread of the data in figure 5 there seems no doubt that this is but an approximation of the facts.

Use the diagram in figure 10 to obtain a grade index for dyed yarns from color measurements. This conversion diagram was prepared from the data in figure 6 in a manner similar to that used for developing the index for bleached yarns. In the yarns dyed after bleaching each unit change of +b (grey yarn) is twice as much as a unit change of R_d. This relationship—placing the index for Middling at 100 and the index for Good Ordinary around 70—was used to develop the following formula:

$$\text{Dyed Yarn Grade Index} = 4(13.5 - \frac{Rd}{2} + b)$$

when: R_d = reflectance of dyed yarn (22s)
b = -b, blueness of dyed yarn (22s)

The constant (13.5) places Middling at 100 and (4) spreads the results so that the index for Good Ordinary is close to 70. Use figure 10 (or this formula) to obtain the grade index for dyed yarns from R_d and b color measurements. Lines of constant index number are centered on the line that best fits the data in figure 6. Even a quick comparison of figures 6 and 10 indicates that on the average the higher grade cottons dye to the deepest color, and therefore have grade index values that are high in comparison to those for low grade cottons. One outstanding exception shows that dyed yarn made from a Strict Low Middling Spotted bale has a higher dyed yarn index than yarns made from any of the Good Middling bales. This is not in error. This particular sample has an unusually high Micronaire reading (5.0) and an unusually low pH (5.7) for such a low grade cotton, but whether these or other factors are responsible for the unusual dye take-up, is not yet known. It is to facilitate the study of relations involved in exceptions of this sort that these grade indexes are so necessary. They will be used in studies of the relationship of quality factors to the finishing properties of cottons, and results will be reported as promptly as they become available.

Table 2 lists color measurements, and the resulting indexes, for the 55 cottons used as a basis for developing the conversion diagrams reported in figures 7 to 10.

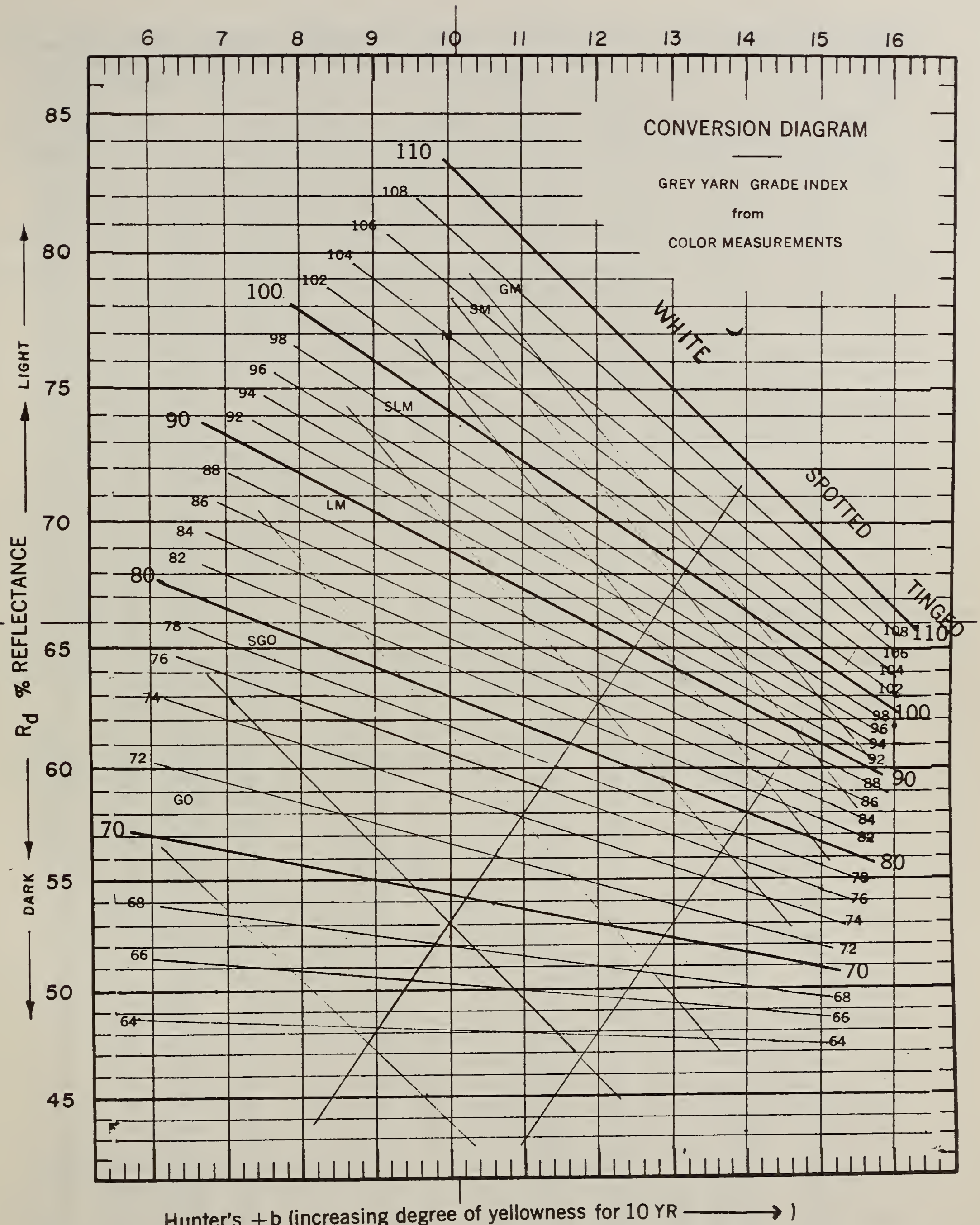


Figure 8.--Diagram for Converting R_d and b measurements of Grey Yarns (22s) to a Grey Yarn Grade Index, 64 through 110.

Table 2.--Data for 55 bales covering the gamut of grades of American Upland cottons. The color data for these samples are used as the basis for developing figures 7-10

Grade by code		Raw stock			Grey yarn			Bleached yarn			Dyed yarn		
		R_d	b	I_R	R_d	b	I_{Grey}	R_d	b	I_{BL}	R_d	b	$I_{B\&D}$
GM	3^4	82.7	8.5	109	74.5	11.4	104	85.1	2.7	106	26.4	26.1	105
	3^1	81.0	9.0	107	74.9	11.3	105	83.4	3.0	101	27.2	25.8	103
	3	79.8	9.8	106	72.1	12.3	104	83.3	3.3	100	25.6	26.8	110
	$3^{5/6}$	78.2	10.5	105	72.1	12.5	105	83.2	3.2	100	25.7	26.4	108
SM	4^1	80.5	8.1	105	72.7	11.3	102	83.7	3.2	101	26.7	26.2	105
	4^2	80.4	8.3	105	72.0	12.4	104	83.2	3.0	101	26.0	26.4	108
	4^4	80.0	8.5	105	74.5	11.3	104	83.7	3.0	102	27.8	25.7	101
	4^3	78.0	9.4	103	71.6	11.5	100	83.3	3.2	100	26.6	26.4	107
	4^5	76.7	9.9	102	72.0	12.8	105	82.7	3.0	100	27.2	26.1	104
SMSp	43(W)	75.6	10.4	101	69.2	13.0	101	81.7	3.6	95	27.0	25.2	101
	43(W)	74.2	10.9	100	68.7	14.1	105	83.7	3.8	99	28.5	25.6	99
	43(Y)	71.2	12.5	96	63.2	14.7	96	82.2	3.8	95	26.8	25.6	103
SMT	44(W)	69.2	13.4	93	61.0	15.4	92	82.5	4.6	93	27.0	25.2	101
	44(M)	67.4	14.0	89	59.6	15.6	89	81.0	4.4	90	27.1	25.3	101
	44	65.0	14.8	84	56.2	16.0	82	82.5	4.4	94	26.0	25.8	105
M	5^1	78.2	7.7	102	73.4	11.1	102	83.2	3.2	100	28.0	25.3	99
	5^4	77.8	8.0	102	72.8	11.0	101	82.8	3.2	99	27.6	25.6	101
	5^2	77.1	8.1	101	72.6	11.5	102	83.7	2.8	103	27.8	26.0	102
	5^3	75.2	9.1	100	72.5	11.5	102	82.6	3.4	98	29.1	25.2	96
	5^5	74.6	9.2	99	70.8	12.2	101	83.8	3.2	101	26.6	25.8	104
	5^6	76.0	9.4	101	70.8	12.4	102	83.4	3.6	99	28.8	25.0	96
MSp	53(W)	71.8	10.5	95	63.2	13.6	90	83.2	4.0	97	25.8	25.8	106
	53(M)	69.9	11.3	92	61.6	13.8	87	82.4	3.8	96	25.6	26.0	107
	53(Y)	68.0	11.9	88	62.6	14.4	90	83.7	4.0	98	25.5	25.8	106
MT	54(W)	65.8	12.8	84	57.8	15.0	82	82.2	4.6	92	27.0	25.0	100
	54(M)	64.2	13.6	82	56.8	15.2	80	80.4	4.6	88	26.9	25.0	100
SLM	6^1	73.0	8.1	95	70.2	11.5	98	83.2	3.2	100	30.9	24.0	88
	6^3	72.0	8.1	94	69.8	10.7	94	83.5	3.2	101	32.2	23.4	83
	6^6	71.1	9.1	93	65.8	12.0	88	82.6	3.6	97	28.1	25.0	98
	6^4	75.6	7.8	99	71.8	10.8	99	82.0	3.6	96	28.5	24.4	95
	6^3	73.0	7.5	95	70.4	11.0	97	84.0	2.8	104	29.2	25.2	96
	$6^{5/6}$	71.0	8.2	92	67.4	12.0	94	81.4	3.2	96	29.8	25.2	95
SLMSp	63(W)	68.2	9.7	87	62.0	12.7	85	80.2	3.9	90	28.3	24.4	95
	63(W)	69.0	10.0	89	65.0	14.0	96	82.0	3.0	98	24.4	28.0	117
	63(M)	67.0	10.5	86	60.6	12.8	82	81.1	4.4	90	26.6	25.0	101
	63(Y)	65.4	11.6	83	59.8	13.5	82	77.2	4.2	82	28.6	23.8	92
	63(Y)	64.7	11.6	82	59.4	13.9	82	83.6	4.0	98	30.2	23.6	88
SLMT	64(W)	63.1	12.2	80	57.2	14.2	79	77.4	4.2	83	27.6	24.0	95
	64(M)	61.2	12.8	76	51.0	13.8	69	80.5	4.6	88	28.1	24.0	94
LM	7^4	68.8	6.3	86	66.4	9.4	84	78.7	3.3	89	28.5	23.8	92
	7^3	66.8	7.3	84	65.0	10.5	85	79.3	5.2	79	32.4	21.8	77
	7^6	67.0	8.9	85	65.4	12.5	91	82.9	3.8	97	29.1	24.8	95
LMSp	73(W)	64.3	9.2	81	61.9	12.9	85	83.3	4.0	97	28.2	24.6	96
	73(W)	65.5	9.8	83	59.3	12.5	79	76.8	3.0	86	29.2	24.2	92
	73(M)	64.5	9.8	81	56.8	12.8	76	75.6	3.4	81	29.2	24.1	92
	73(Y)	63.5	10.3	80	56.2	13.0	75	75.3	3.6	80	28.6	24.0	93
LMT	74(W)	58.6	11.8	72	51.2	13.1	68	79.4	4.4	86	28.4	24.1	93
	74(Y)	55.0	13.6	67	49.8	14.0	68	79.4	4.9	85	26.9	24.1	96
SGO	8^1	64.0	6.6	79	64.4	9.4	81	77.8	3.7	85	32.4	22.3	79
	8^4	62.3	6.0	77	62.2	8.7	76	76.9	3.4	85	30.4	22.7	84
	8^3	60.2	7.1	74	62.6	10.7	81	81.4	4.0	90	31.6	22.9	83
	8^6	61.2	8.1	76	61.8	11.2	80	78.4	4.1	85	29.6	23.2	87
GO	9^4	55.8	5.8	70	60.9	8.9	75	77.4	3.7	85	30.6	22.8	85
	9^2	56.7	6.4	71	53.0	7.8	68	67.2	4.0	59	32.5	19.0	65
	9^3	55.0	6.8	69	55.0	8.5	70	72.4	3.4	74	34.2	20.4	67

Note: The index figures are coded as follows: for raw stock, I_R; for grey yarn, I_{Grey}; for bleached yarn, I_{Bl}; for yarn dyed after bleaching, $I_{B\&D}$

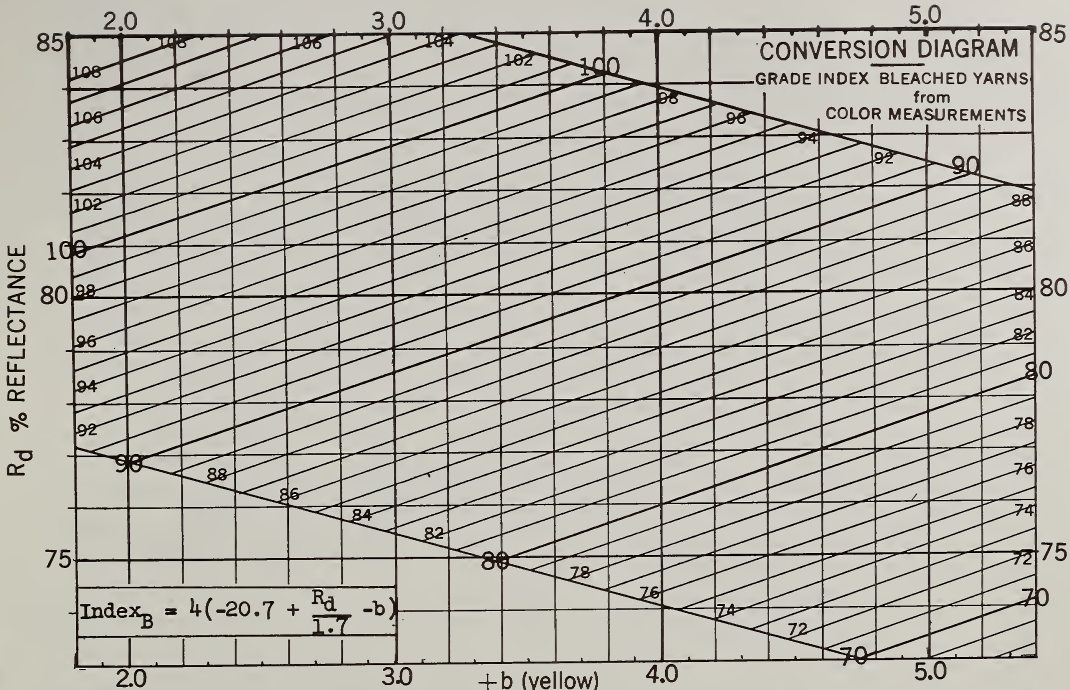


Figure 9.--Diagram (and formula) for Converting R_d and b measurements of Bleached Yarns (22s) to a Bleached Yarn Grade Index, 70 through 108.

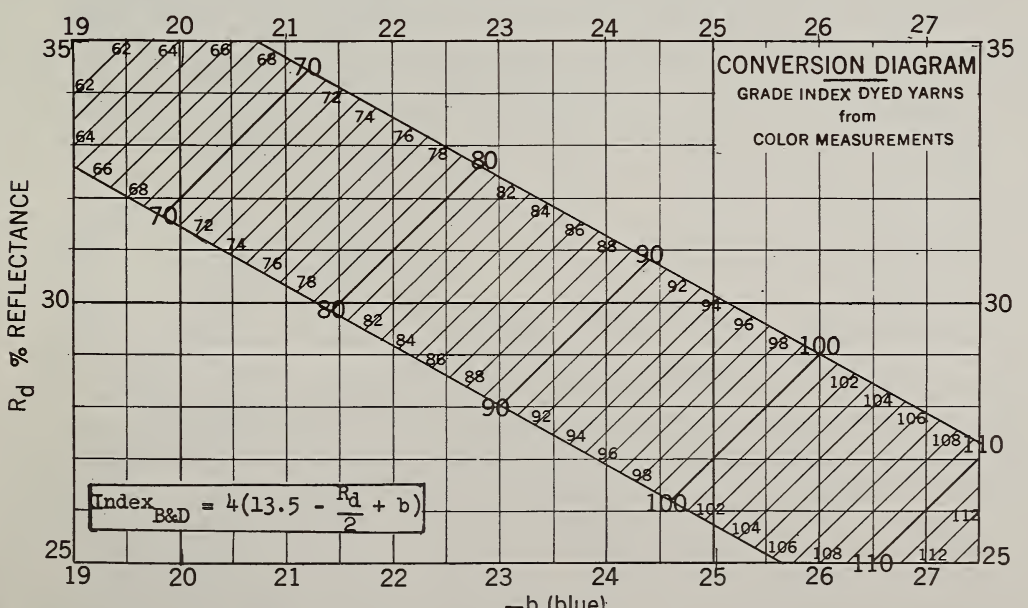


Figure 10.--Diagram (and formula) for Converting R_d and b measurements of yarns dyed Blue after bleaching to a Dyed Yarn Grade Index, 62 through 112.

LITERATURE CITED

(1) United States Department of Agriculture
1956. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1955. Agri. Mktg. Serv. No. 152

(2) ______
1956. Bleaching, Dyeing and Mercerizing Test Results on Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1955. Agri. Mktg. Serv. No. 167

(3) ______
1957. Summary of Fiber and Processing Test Results on Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1956. Agri. Mktg. Serv. No. 170

(4) ______
1958. Summary of Fiber and Processing Test Results on Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1957. Agri. Mktg. Serv. No. 186

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COTTON GRADE STUDIES

COLOR MEASUREMENTS OF GRADE STANDARDS, 1952 - 1959

A series of diagrams prepared for use at the
1959 Universal Grade Standards Conference
Washington, D. C., May 25 - 27, 1959

by

Dorothy Nickerson
Josephine J. Tomaszewski
Standardization Section
Standards and Testing Branch

* * * * *
* * *
*

Administrative Use

Washington 25, D. C.

May 1959
No. 1 of 4 reports

Table of Contents (1)

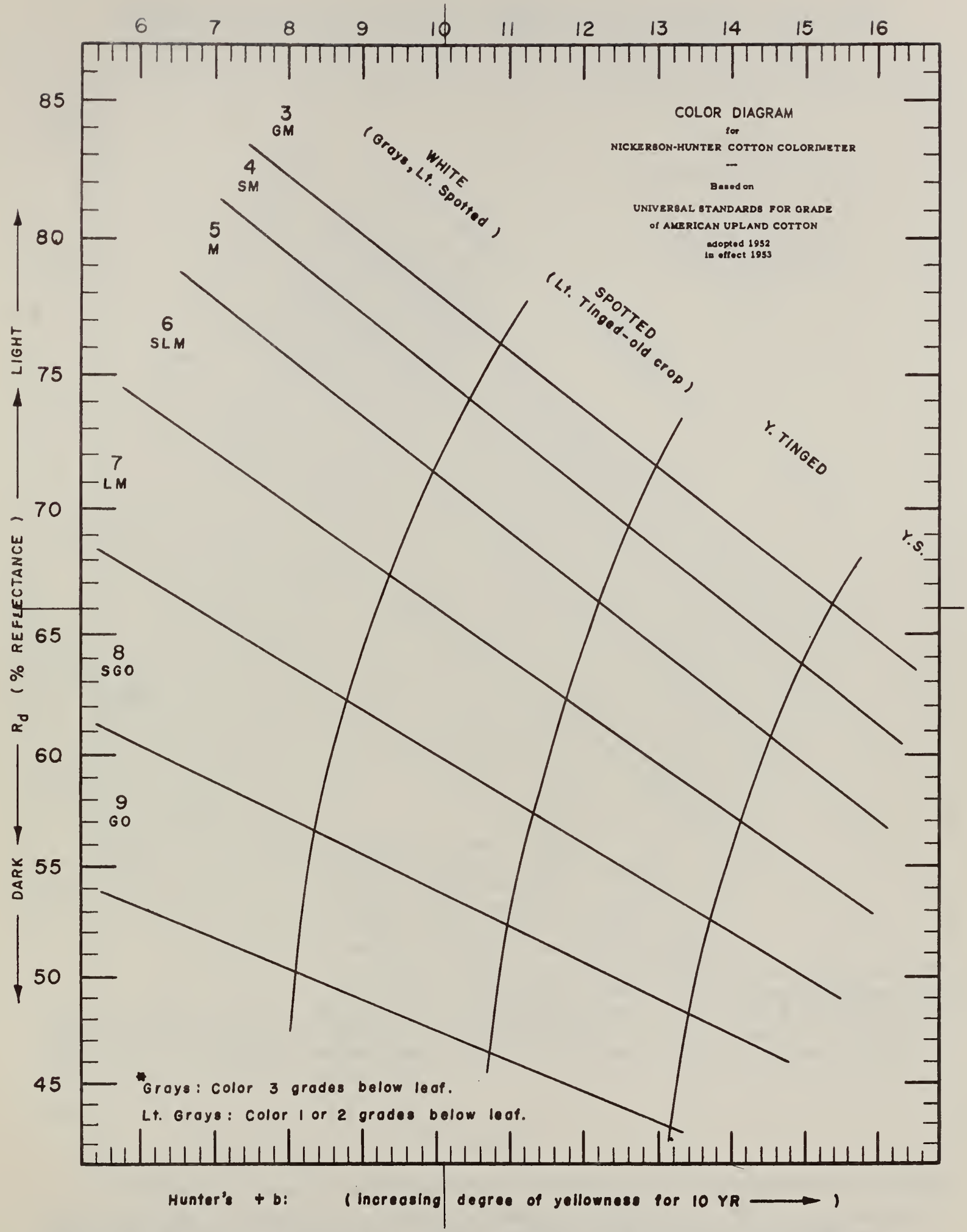
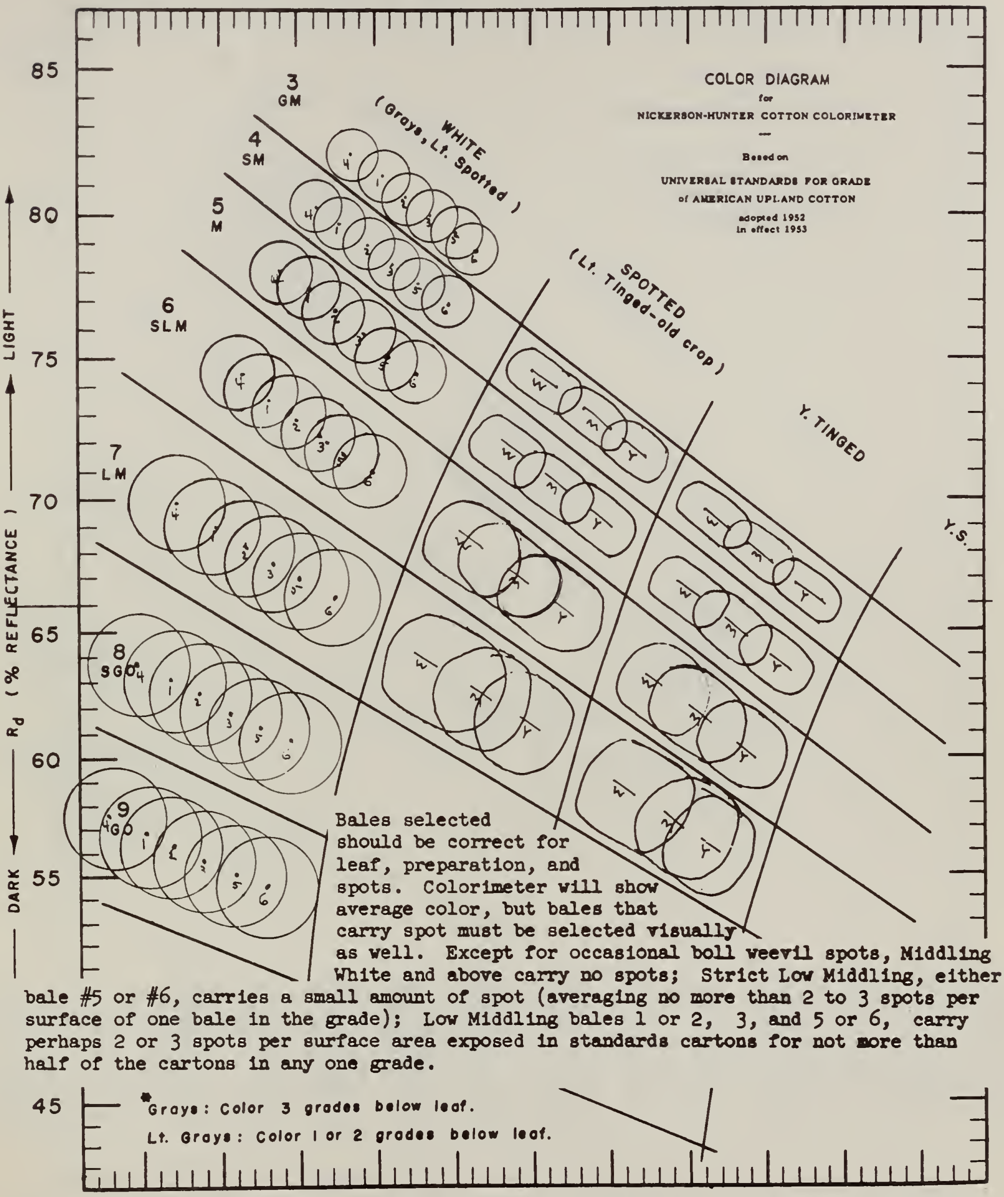


FIGURE 1.--COLOR DIAGRAM OF COTTON GRADES FOR THE NICKERSON-HUNTER COTTON COLORIMETER.

Color has three dimensions (hue, lightness, and chroma) but hue is so nearly constant for cotton that measurements of lightness and chroma are sufficient to define the color of cotton grades. Hunter scales used in this instrument are indicated in a vertical direction by percent reflectance (R_d), which measures the lightness of a sample, and in a horizontal direction by Hunter's +b which, for this instrument, indicates the degree of yellowness (with hue constant), and thus provides a measure of chroma. High grades are toward the top of the diagram, low grades toward the bottom; gray colors are toward the left, and tinged or stained colors toward the right. The original of this diagram fits over the diagram on the instrument, so that indicated points may be plotted directly.

Guides for purchase of bales for standards. Dots (white grades) and short lines (spots and tinges) represent color positions wanted. Circles and ellipses indicate range of samples expected within purchased bales.

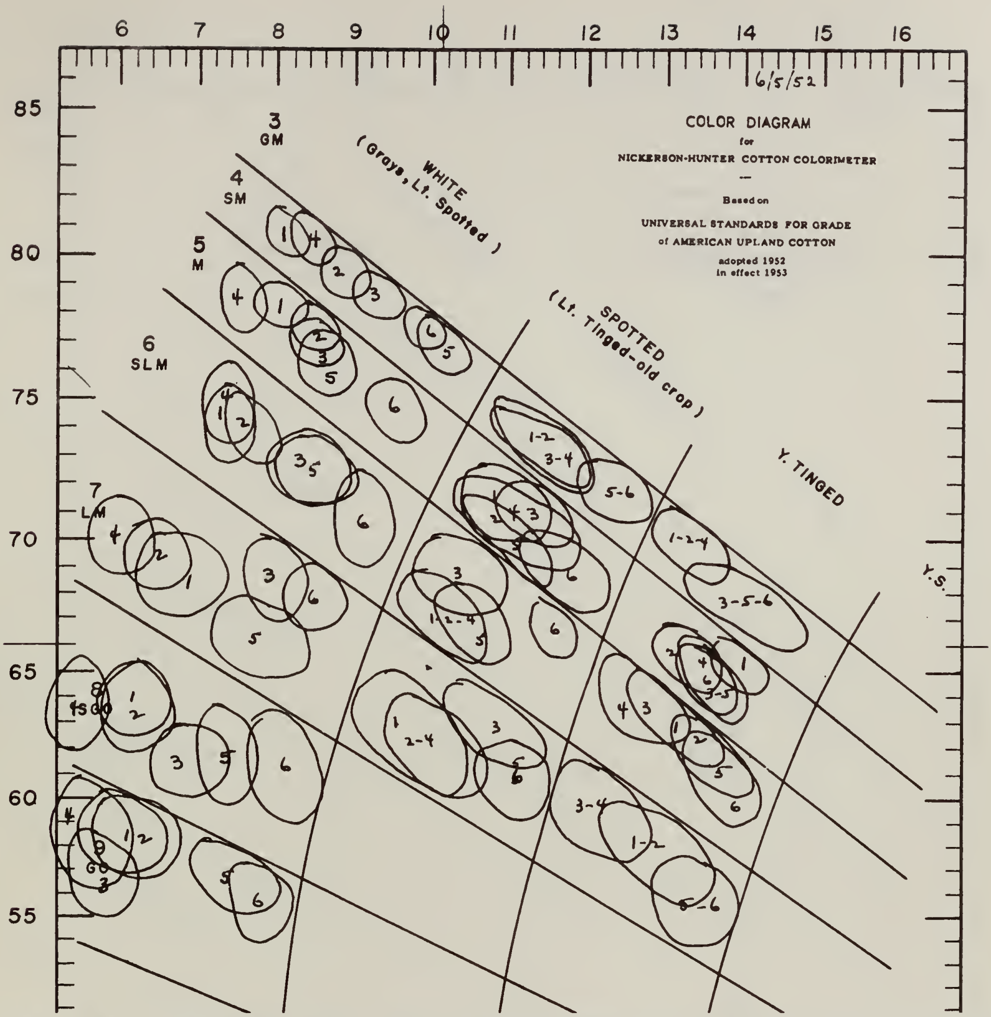


Bales selected should be correct for leaf, preparation, and spots. Colorimeter will show average color, but bales that carry spot must be selected visually as well. Except for occasional boll weevil spots, Middling White and above carry no spots; Strict Low Middling, either bale #5 or #6, carries a small amount of spot (averaging no more than 2 to 3 spots per surface of one bale in the grade); Low Middling bales 1 or 2, 3, and 5 or 6, carry perhaps 2 or 3 spots per surface area exposed in standards cartons for not more than half of the cartons in any one grade.

Bale positions 1,2 represent S.Central cottons; 3, Southeast; 4, West; 5,6,Southwest. For Spots and Tinges three colors W(hite), M(edium); and Y(ellow) are required.

FIGURE 2.--COLOR GUIDE FOR PURCHASE OF BALES FOR COTTON GRADE STANDARDS.

This guide is based on standards adopted in 1953 that were, in turn, based on crop survey data available for many years. Color for positions in White grades is based on the relation of the average grade color for cottons grown and classed in four cotton areas over a period of many years.



	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	129245	876309	68328	136293	136004	695464	367656	753450	250517	32374	380046	2639716	13427	11667
2	146897	149430	1084395	879593	136005	695564	367565	499916	250517	2771	380046	13173	13427	11667
3	15294	17534	8449922	825	372322	1350315	677816	677808	179735	759793	713627	13155	17417	18218
4	588016	564143	405229	1667914	7797614	608667	677816	751034	250517	2771	380046	2597143	24078	18218
5	266981	178953	2644949	22838	2446522	13121	542617	261428	10891	28941	713627	13155	26915	11824
6	110856	266843	31601	2629166	13115	13155	542617	2657539	24078	11642	713627	13173	13369	11824

FIGURE 3.--COLOR OF BALES PURCHASED FOR USE IN PREPARING GRADE STANDARDS ADOPTED IN 1952.

The Original Set, #101, was selected from boxes put up from these bales.

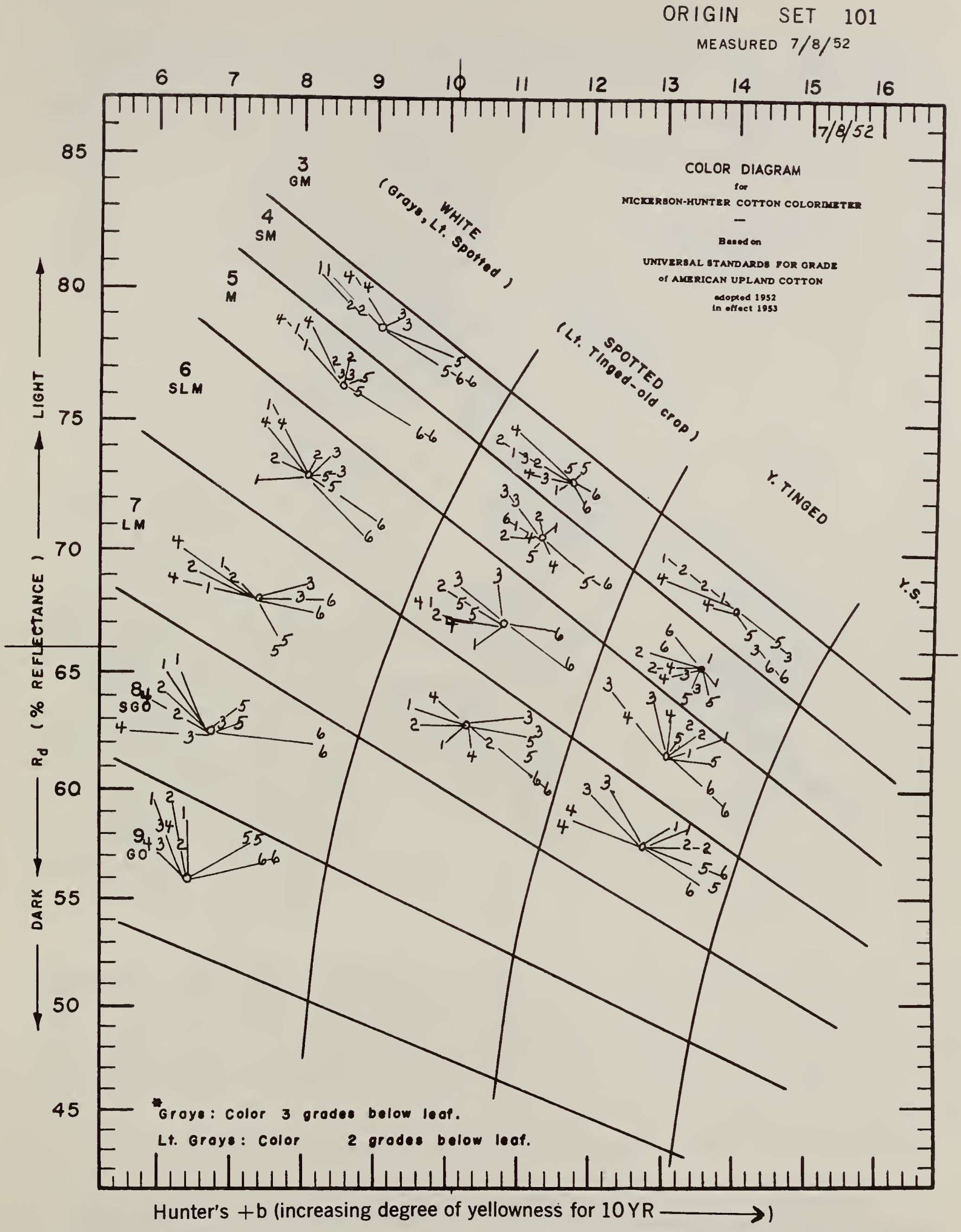
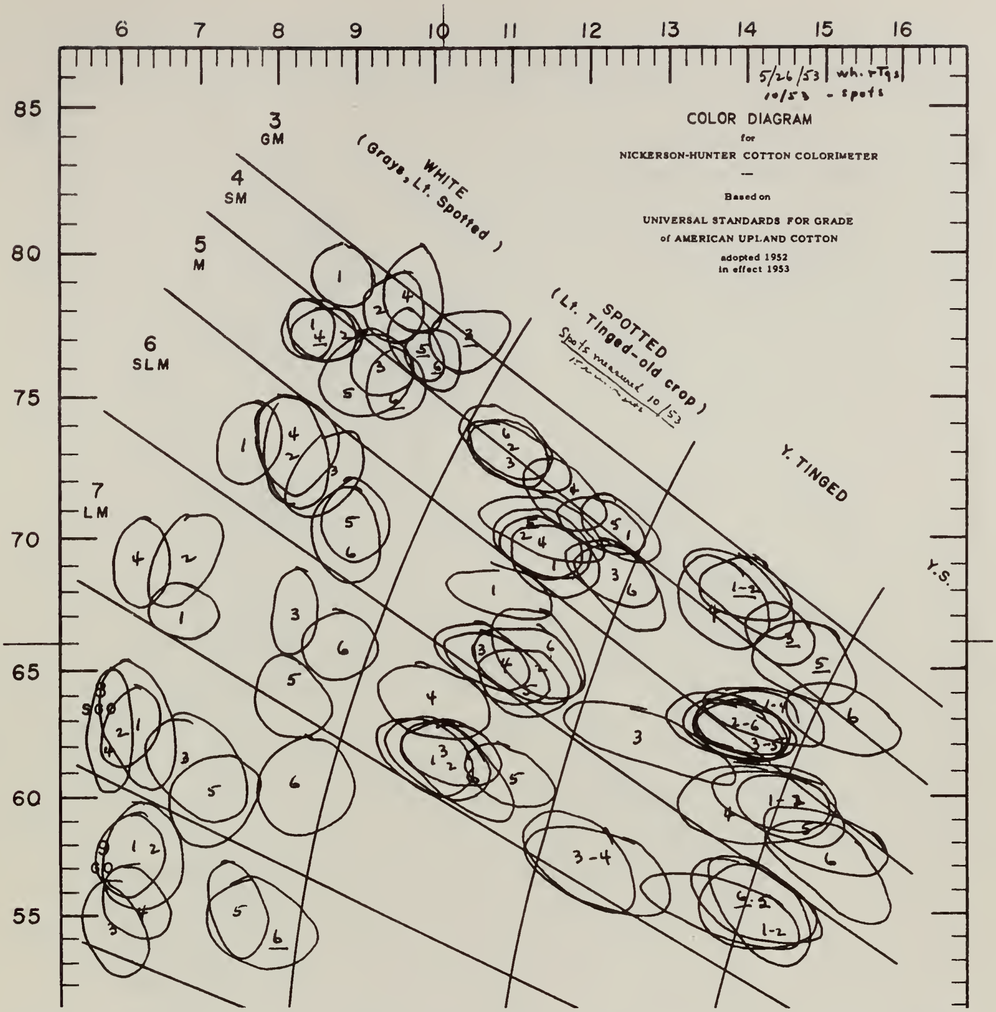
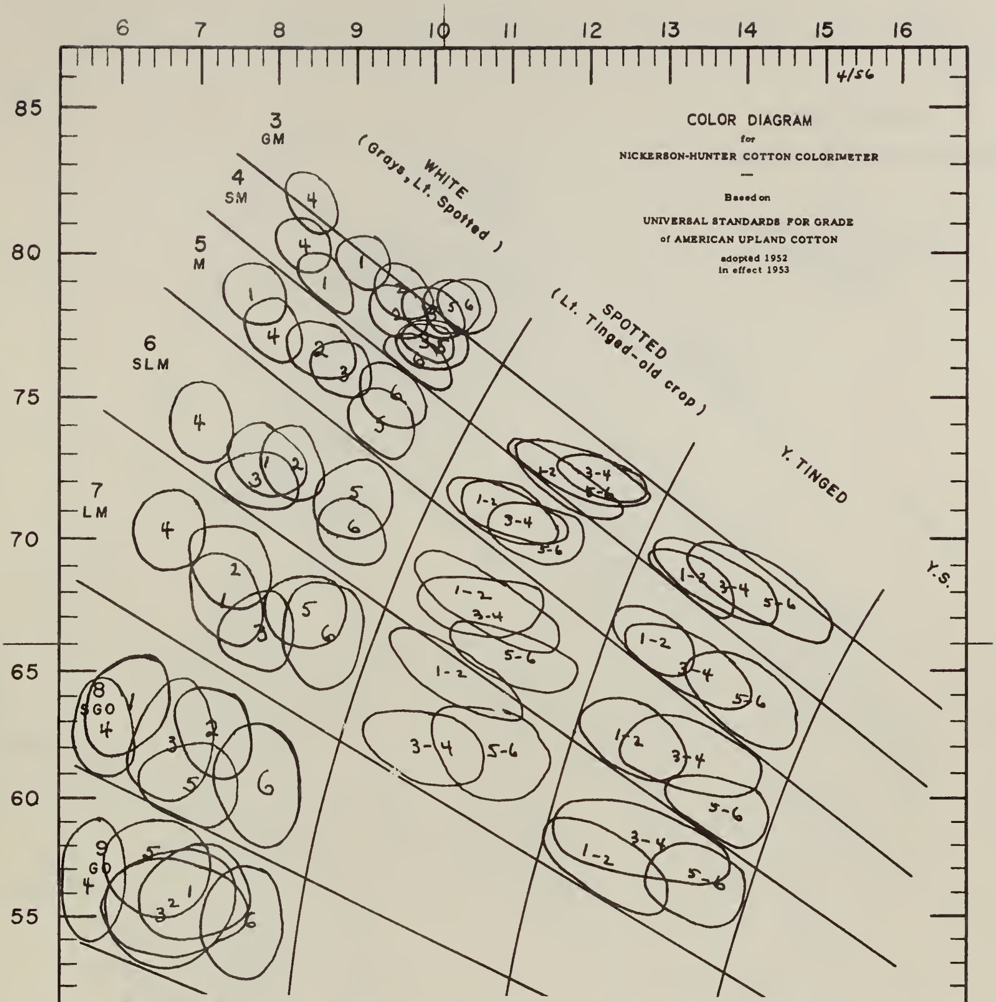


FIGURE 4.--COLOR OF GRADE STANDARDS, ORIGINAL SET, #101, APPROVED IN 1952, PROMULGATED FOR USE AUGUST 1, 1953.



	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 Sp	7 Sp	4T	5T	6T	7T
1	129245	876309	68328	136293	136004	695464	367656	677808	19191	32374	19081	2597143	13427	11667
2	146897	149430	1084395	879593	136005	695564	19192	499916	10842	2771	19081	13193	13427	11667
3	19220	17534	849922	825	372322	1350315	19193	677455	19108	19181	703777	13155	17417	18218
4	588016	564143	405229	1667914	7797614	608667	19159	19118	19108	19122	380046	2597143	24078	18218
5	19067	178953	2644949	22838	2446522	13121	542617	677808	10891	250578	19090	13155	2694155	18600
6	19066	172953	31601	2629166	13115	13120	19193	550024	179735	2771	713627	13173	13369	18958

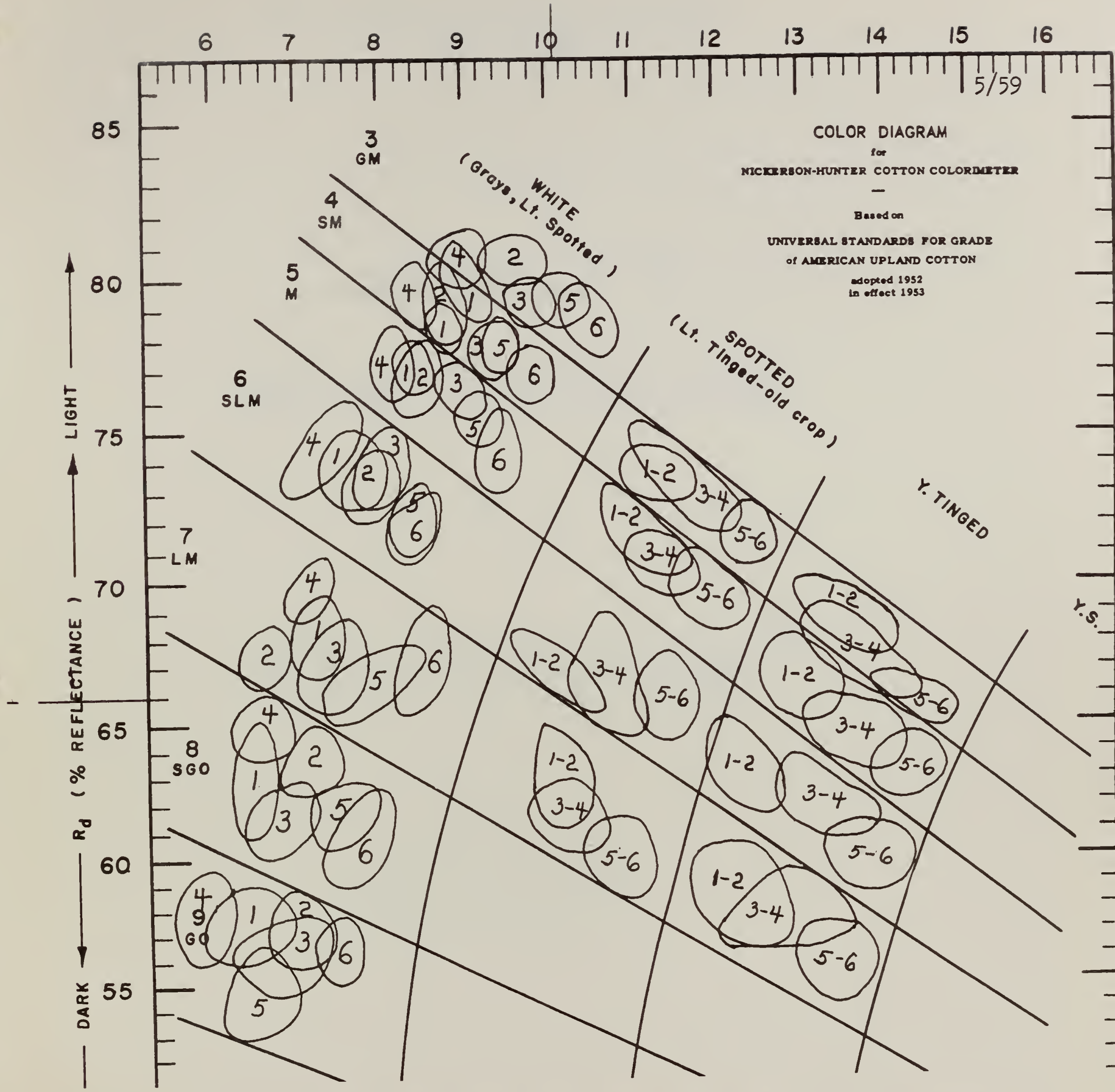
FIGURE 5.--COLOR OF BALES USED IN GRADE STANDARDS PASSED AT THE 1953 CONFERENCE. Underlined bale positions already had to be replaced because of color change from bales in original box.



	GM	SM	M	SLM	LM	SGO	GO	4T	5T	6T	7T
1	19642	19567	19652	19478	19522	19673	19262	19690	19495	19390	19705
2	19566	19569	19606	19520	19481	19482	19261				
3	19595	19592	19587	19455	19349	19218	19352	19525	19658	19447	19692
4	19588	19573	19600	19636	19505	19670	19693				
5	19544	19580	19563	19511	19496	18153	19698	19700	19291	19490	19278
6	19542	19582	19564	19612	19127	18151	19703				

FIGURE 6.--COLOR OF BALES USED IN GRADE STANDARDS AND GUIDES PASSED AT 1956 CONFERENCE.

These measurements are based on 110 sets of White and Tinged standards put up for the conference, and on 20 boxes of Spotted guides. Bale numbers for Spotted guides are — 4Sp; 19192, 19180, 19506: 5Sp; 19686, 19701, 19722: 6Sp; 19684, 19702, 19107: 7Sp; 19638, 32374, 27771.



	GM	SM	M	SLM	LM	SGO	GO	4Sp	5Sp	6Sp	7Sp	4T	5T	6T	7T
1	20317	20193	20214	20266	20180	20046	20098	20301	20013	20277	20282	20296	20316	20318	20305
2	20016	20038	20186	20041	20141	20172	20056								
3	20246	20197	20228	20229	20174	20047	20151	20300	19885	20279	20308	20253	19883	20307	20037
4	20234	20203	20272	20269	20285	20136	20148								
5	20001	20167	20195	20182	20215	20059	19926	20081	19701	19895	20303	20298	19440	20334	20335
6	20160	20158	20194	19978	20417	20241	20029								

FIGURE 7.--COLOR OF BALES USED IN GRADE STANDARDS PRESENTED TO THE 1959 CONFERENCE.

Range of color for random sets of White, Tinged, and Spotted grades as put up for the 1959 Universal Grade Standards Conference.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COTTON GRADE STUDIES

SUMMARY OF COLOR MEASUREMENTS FROM SURVEYS OF COTTONS CLASSED IN 8 CROP YEARS, 1951 TO 1958

A series of diagrams prepared for use at the
1959 Universal Grade Standards Conference
Washington, D. C., May 25 - 27, 1959

by

Dorothy Nickerson
Josephine J. Tomaszewski
Standardization Section
Standards and Testing Branch

Administrative Use

Washington 25, D. C.

May 1959
No. 2 of 4 reports

Contents (2)

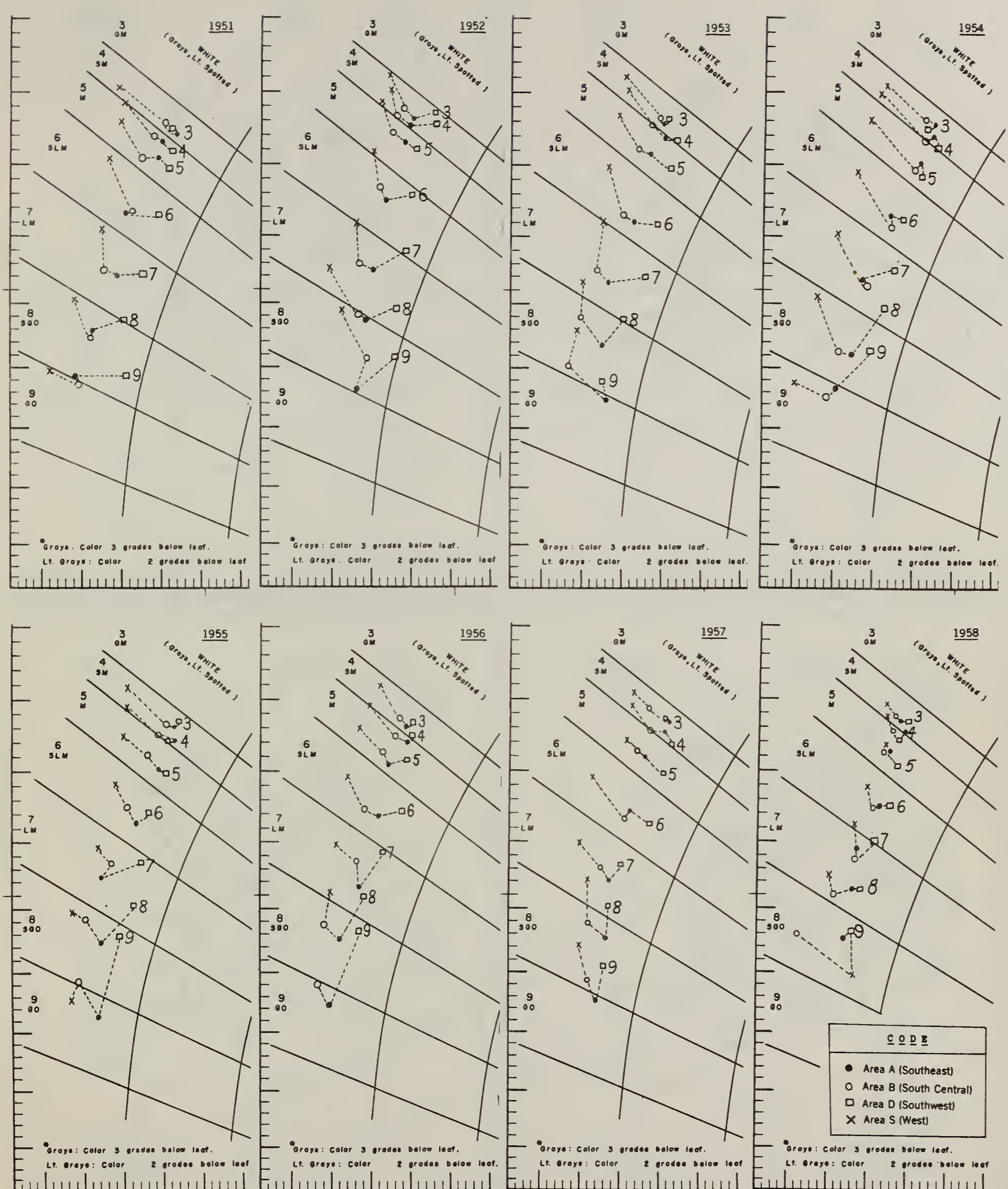


FIGURE 1.--AVERAGE COLOR OF COTTON CLASSED IN WHITE GRADES: 1951-1958, BY AREAS FOR EACH YEAR.

NUMBERS REPRESENT USUAL CODE FOR GRADES: 3 TO 9, GM TO GO.

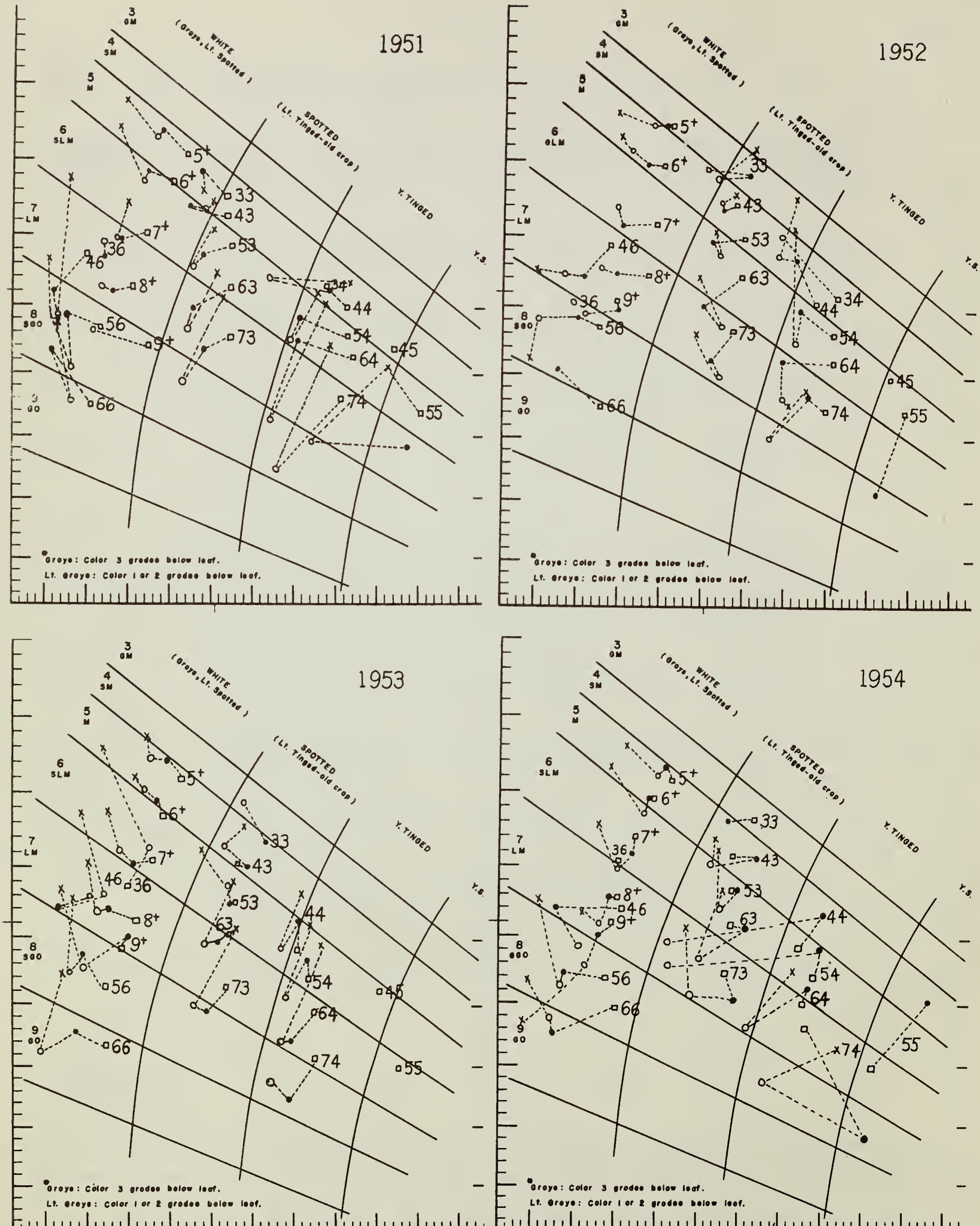


FIGURE 2.--AVERAGE COLOR OF COTTON CLASSED IN GRAY, PLUS, SPOTTED, TINGED, AND YELLOW STAINED GRADES: 1951-1958, BY AREAS FOR EACH YEAR.

CODE AND SYMBOLS ARE THOSE USED BY COTTON DIVISION, AMS (CN 918-4, EXHIBIT C, 6/56). E.G., 3 TO 9 = GM TO GO, COMBINED WITH NUMBERS TO INDICATE SPOTTED, TINGED, ETC., AS 5+ = MIDDLING PLUS, 53 = MIDDLING SPOTTED, 54 = MIDDLING TINGED, 55 = MIDDLING YELLOW STAINED, AND 56 = MIDDLING GRAY.

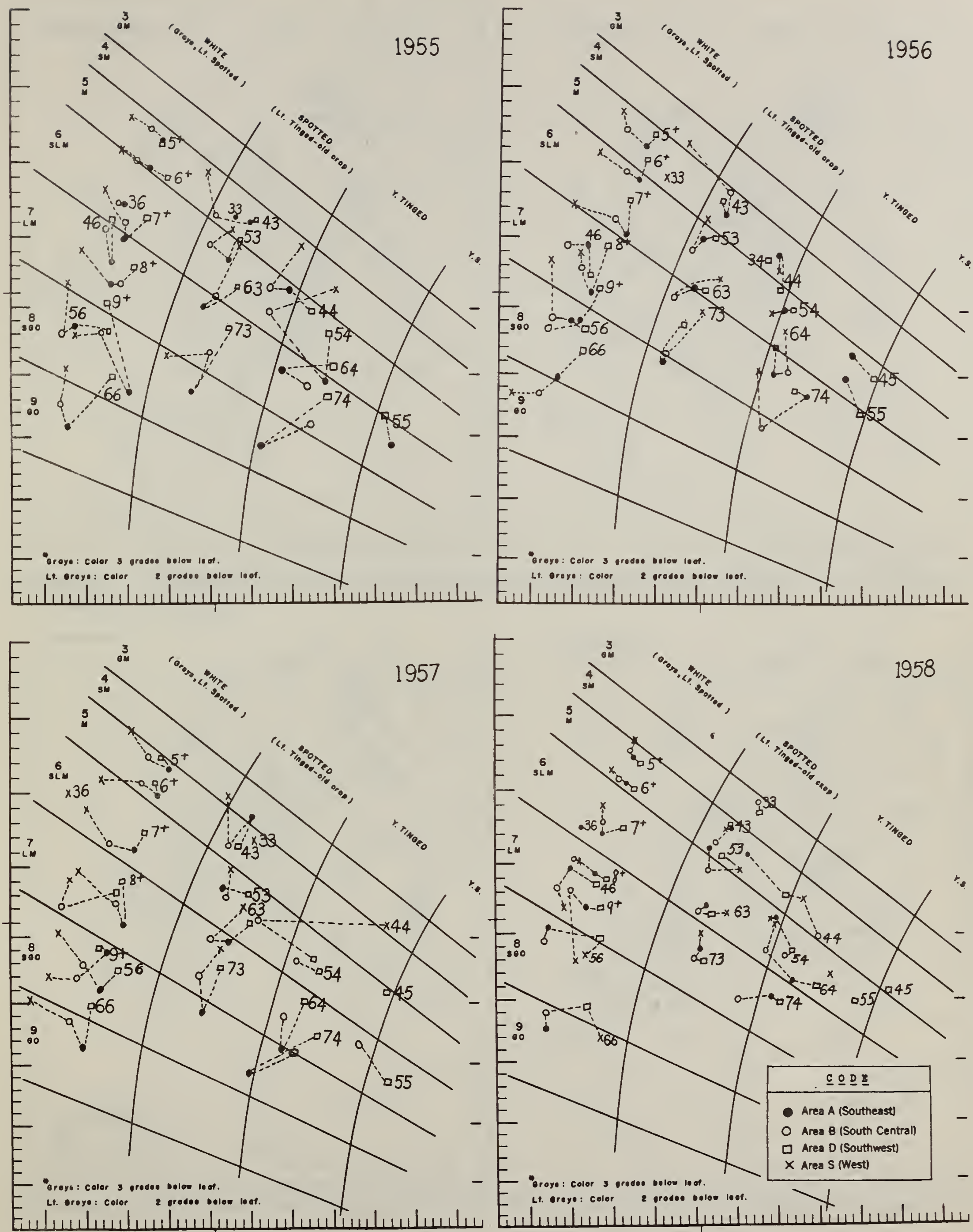


FIGURE 2.--Cont'd. AVERAGE COLOR OF COTTON CLASSED IN GRAY, PLUS, SPOTTED, TINGED, AND YELLOW STAINED GRADES: 1951-1958, BY AREAS FOR EACH YEAR.

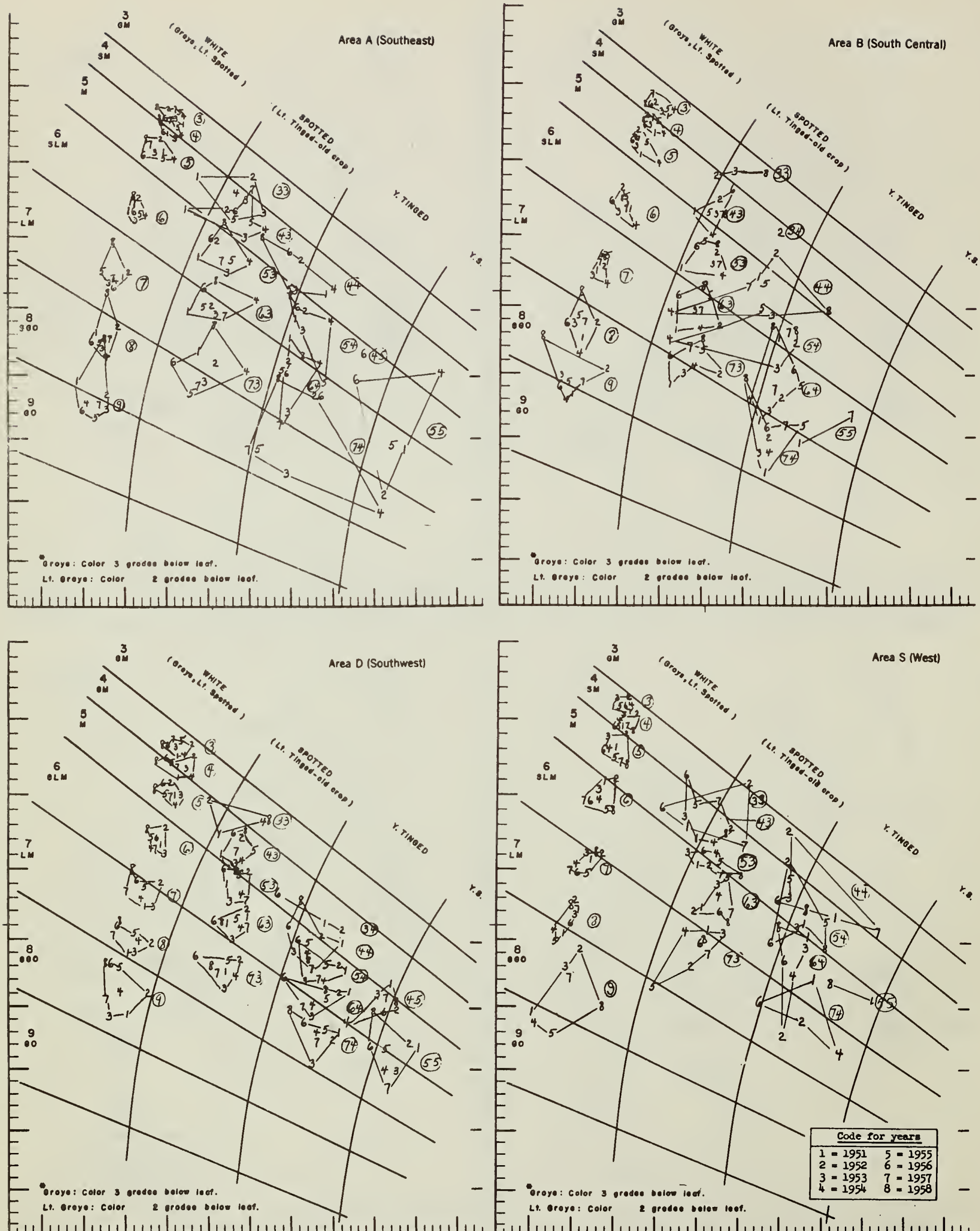


FIGURE 3.--AVERAGE COLOR OF COTTON CLASSED IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES: BY YEARS FOR FOUR AREAS.

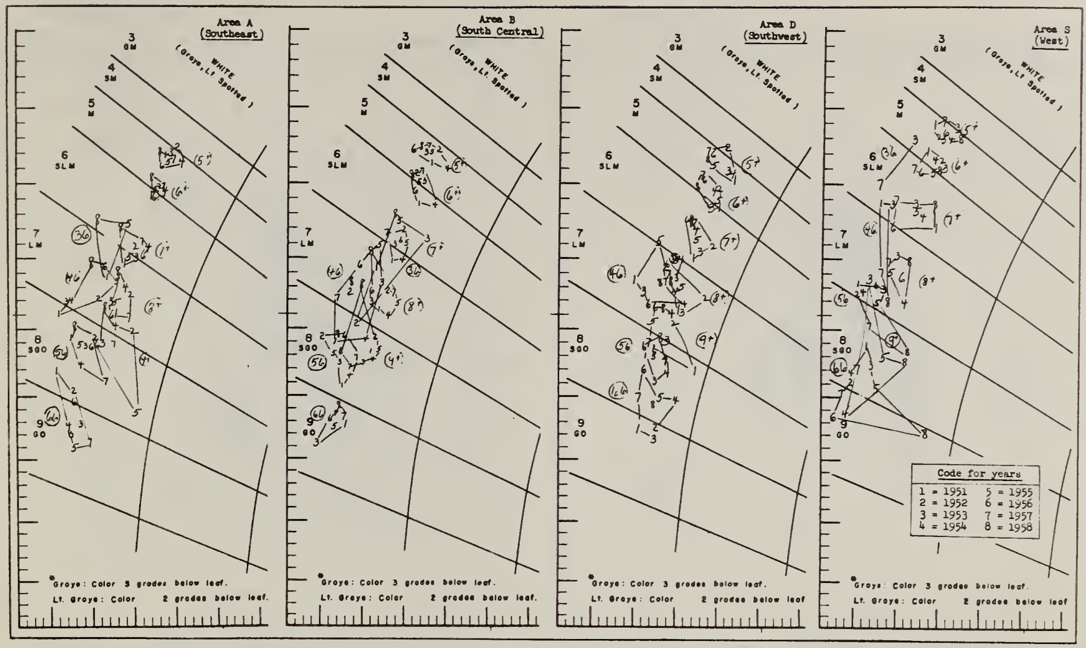


FIGURE 4.--AVERAGE COLOR OF COTTON CLASSED IN PLUS AND GRAY GRADES: BY YEARS FOR FOUR AREAS.

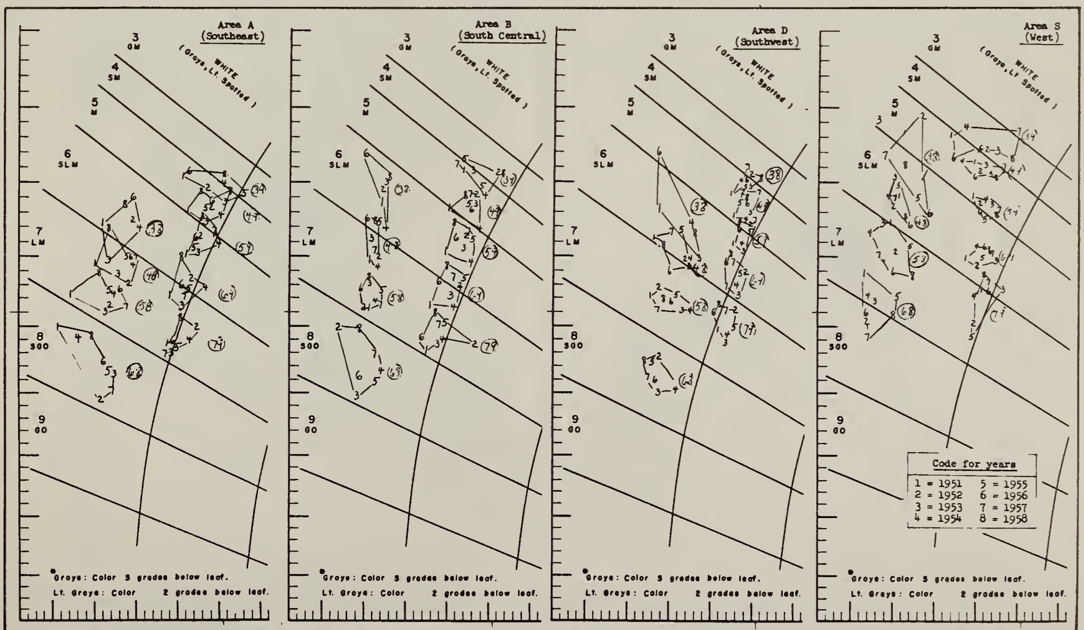


FIGURE 5.--AVERAGE COLOR OF COTTON CLASSED IN LIGHT GRAY AND LIGHT SPOTTED GRADES: BY YEARS FOR FOUR AREAS.

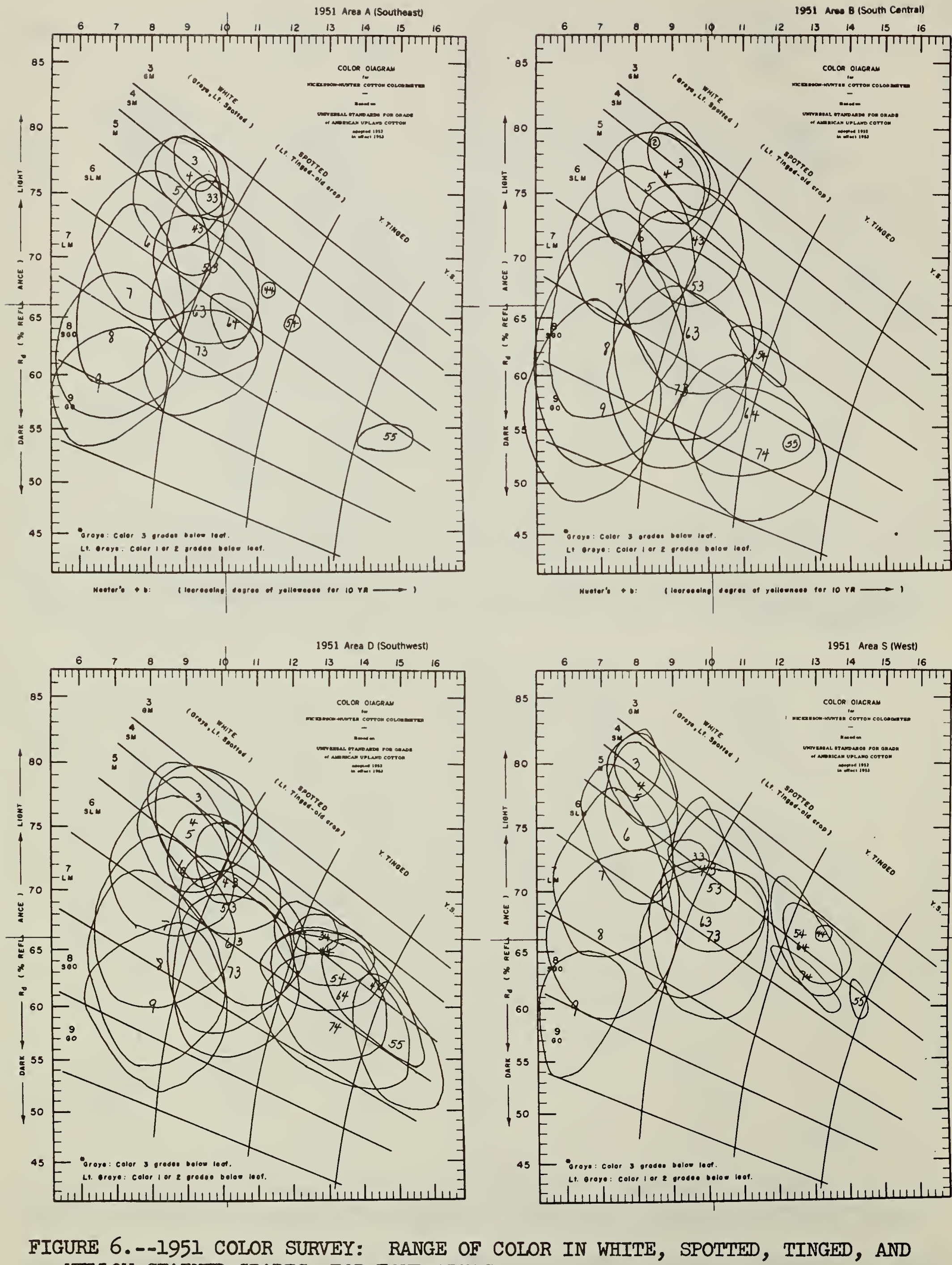


FIGURE 6.--1951 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

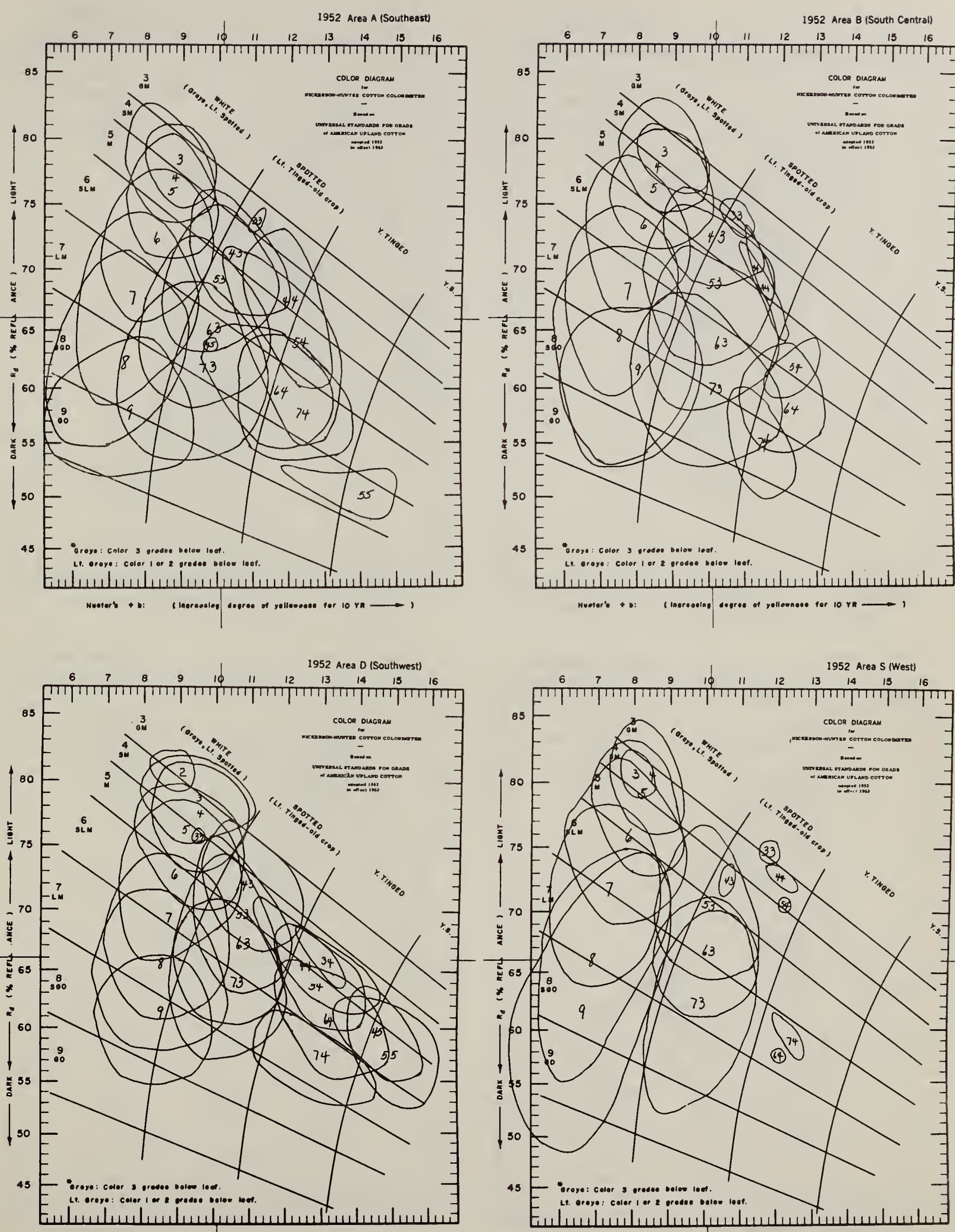


FIGURE 7.--1952 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

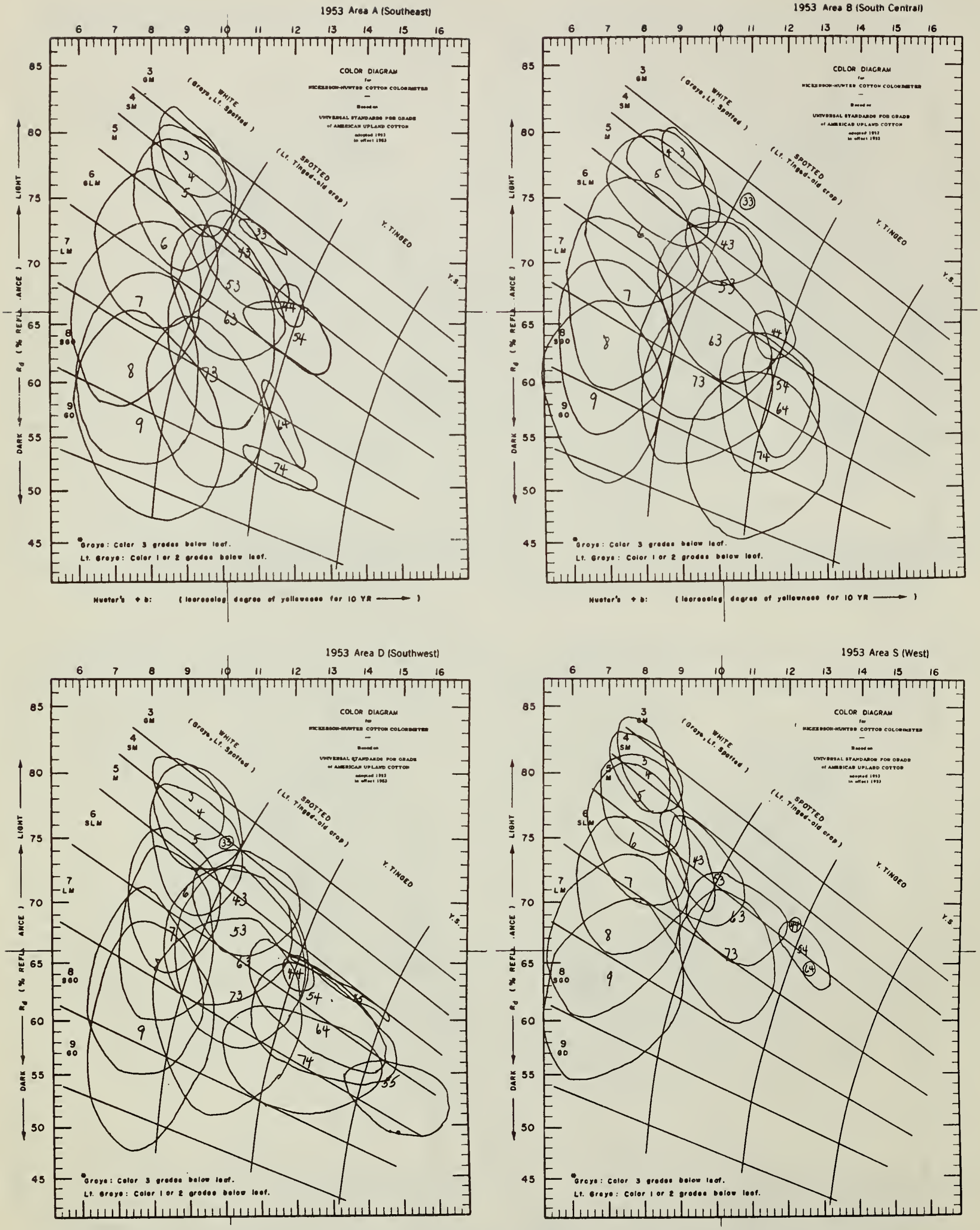


FIGURE 8.--1953 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

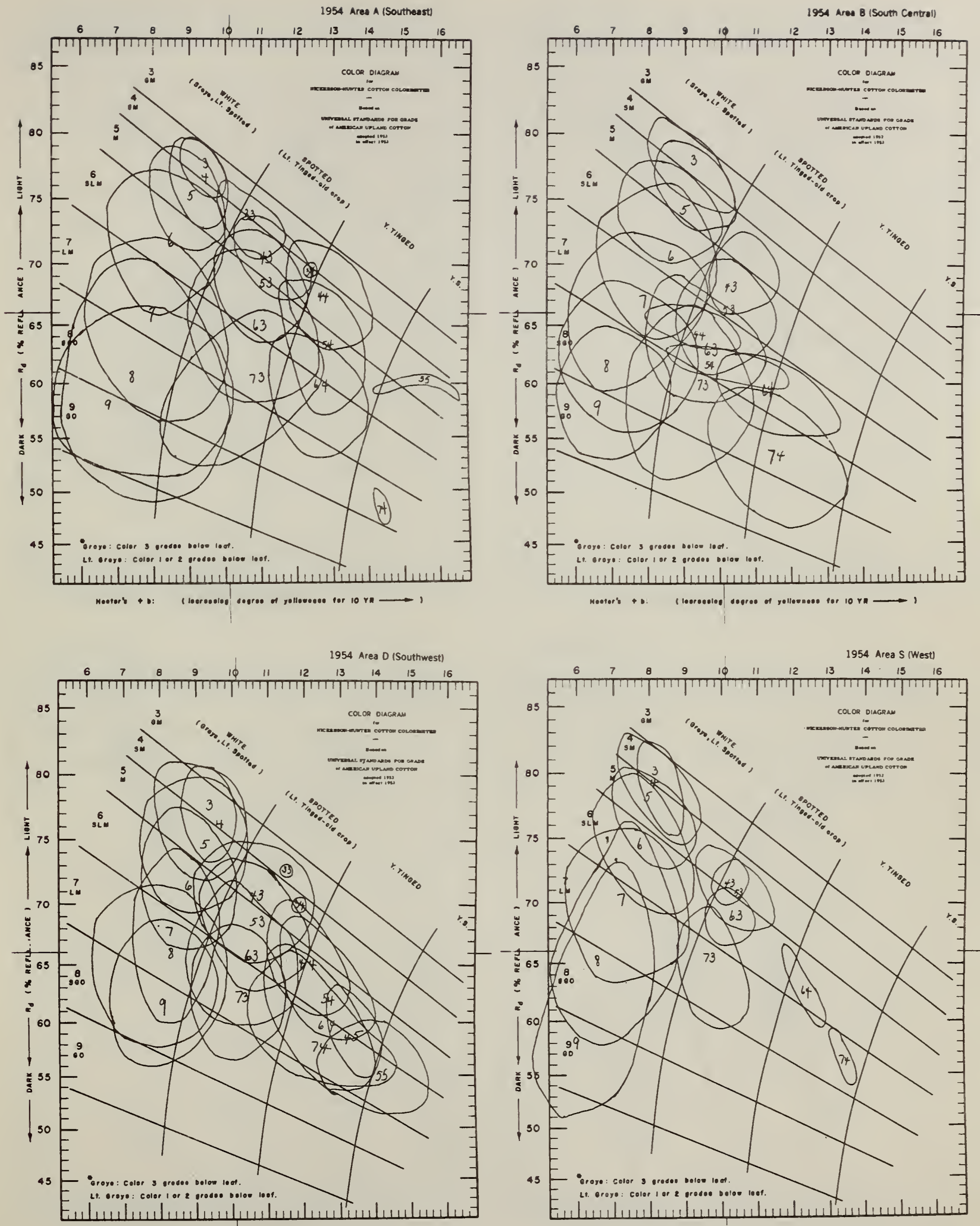


FIGURE 9.--1954 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

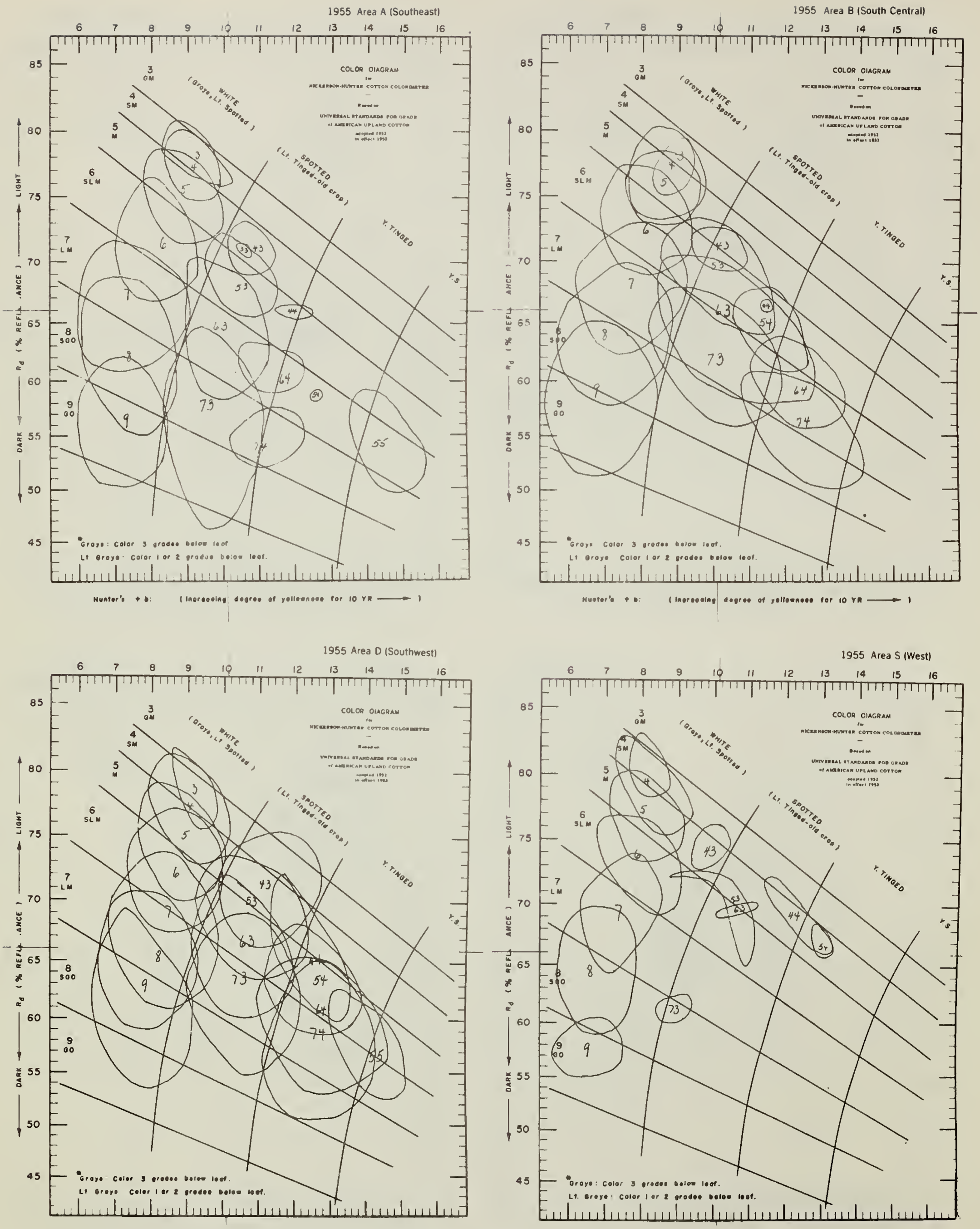


FIGURE 10--1955 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

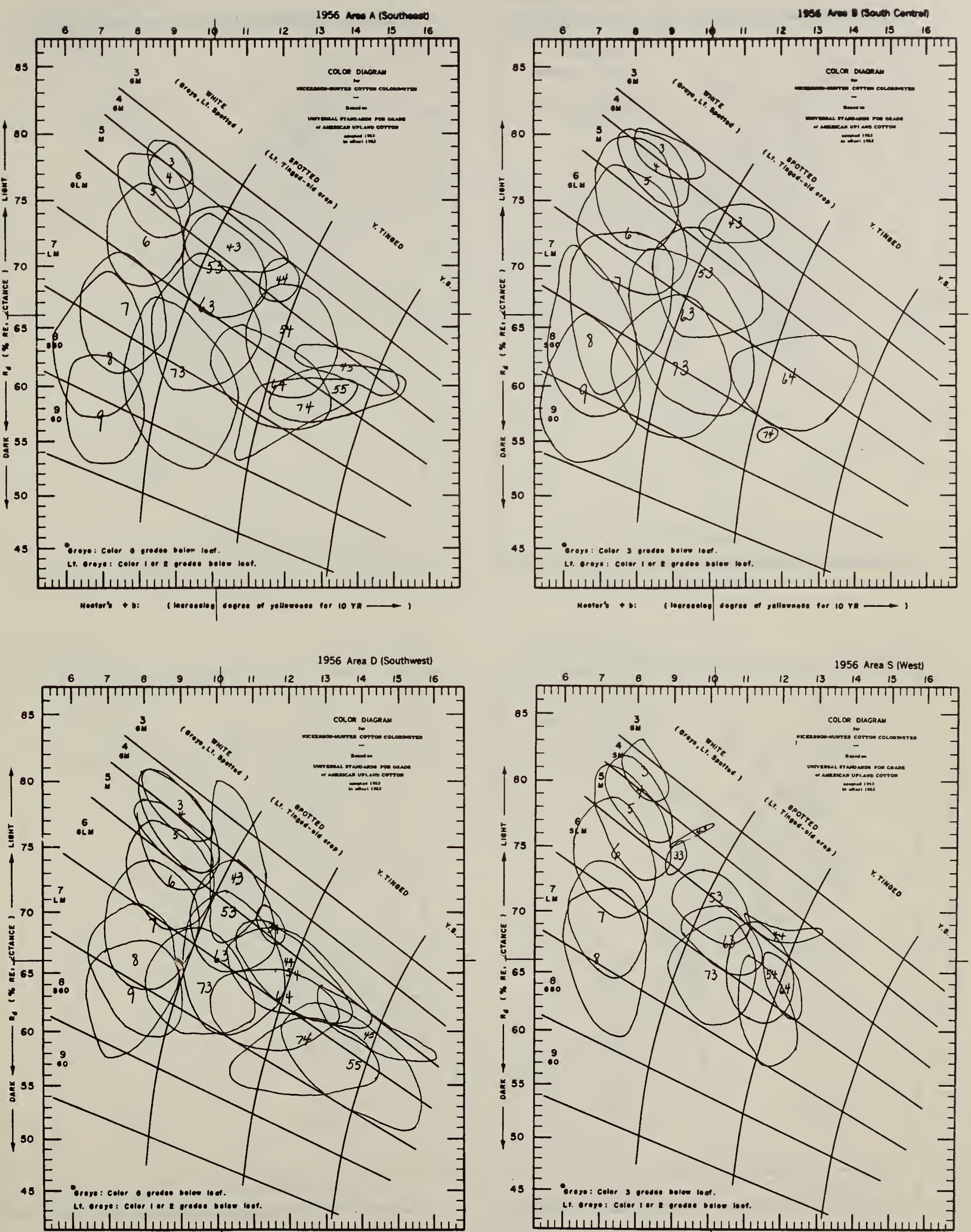


FIGURE 11.--1956 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

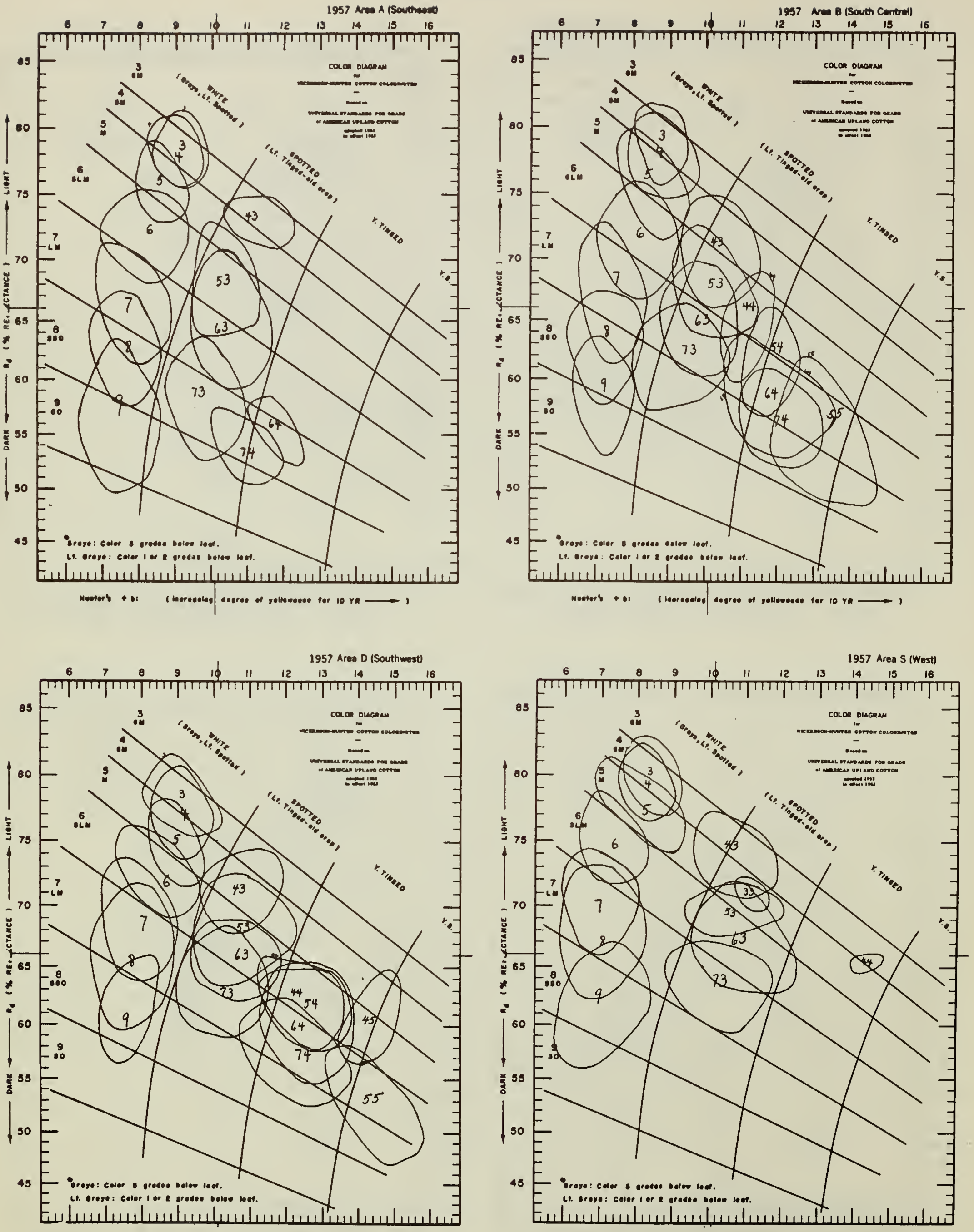


FIGURE 12.--1957 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

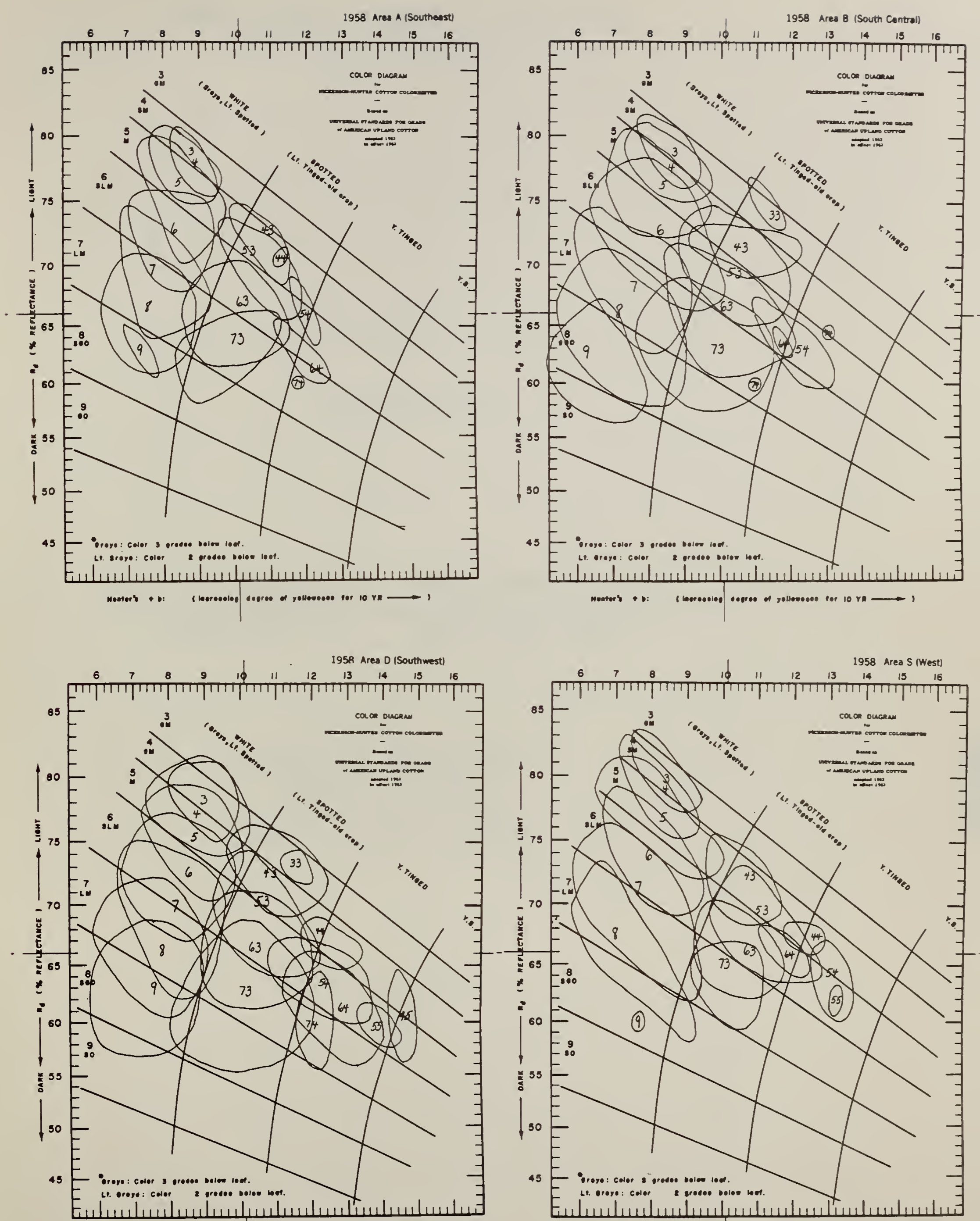


FIGURE 13.--1958 COLOR SURVEY: RANGE OF COLOR IN WHITE, SPOTTED, TINGED, AND YELLOW STAINED GRADES; FOR FOUR AREAS.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COTTON GRADE STUDIES

TRASH AND COLOR

A series of diagrams and tables prepared for use at the 1959 Universal Grade Standards Conference
Washington, D. C., May 25 - 27, 1959

by

Dorothy Nickerson
Josephine J. Tomaszewski
Franklin E. Newton
Standardization Section
Standards and Testing Branch

* * * * *
* * *
*

Administrative Use

Washington 25, D. C.

May 1959
No. 3 of 4 reports

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

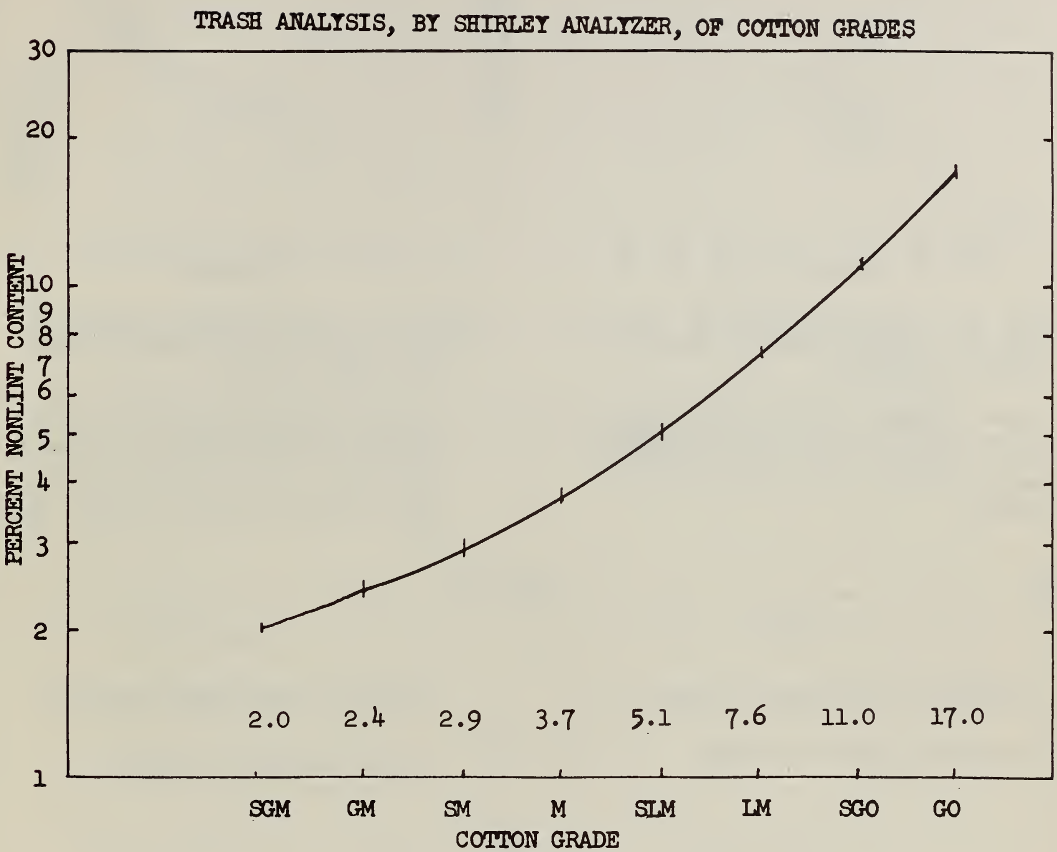


FIGURE 1.--CURVE REPRESENTING AVERAGE NONLINT IN COTTON GRADE STANDARDS.

Target for 1952/3 standards, based on measurements of previous standards, 1936 and 1946. Used unchanged since then as reference curve for nonlint in cotton standards.

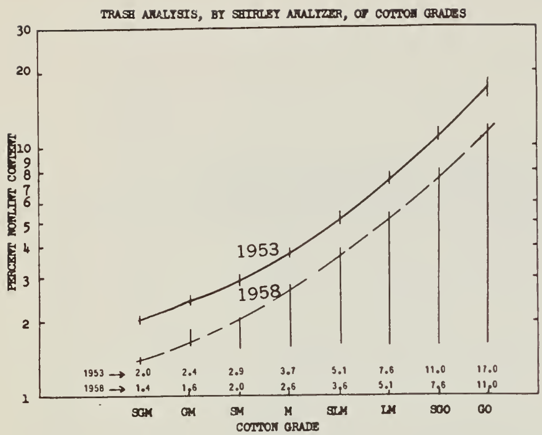


FIGURE 2.--AVERAGE NONLINT OF 1958 CROP VS. AVERAGE NONLINT IN WHITE COTTON STANDARDS.

To keep standards at the 1953 level, trash must be adjusted on the surface of standards bales. Effects of current ginning practices are illustrated by the difference between curves.

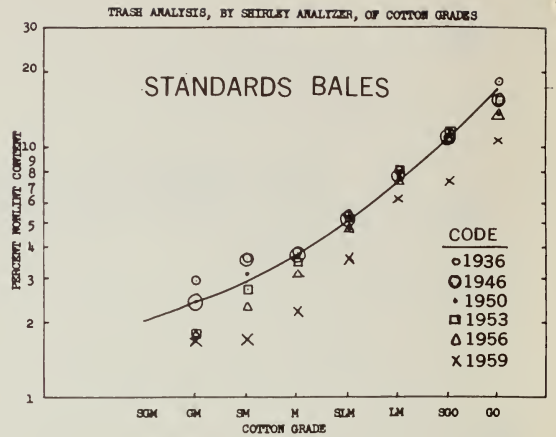


FIGURE 3.--AVERAGES OF NONLINT IN BALES USED IN WHITE GRADE STANDARDS (1936-1959).

To adjust for decreasing amounts of trash in bales that match the standards for color, trash must be added to surface of bales. Color cannot be adjusted, therefore the leaf must be adjusted to match the official standards.

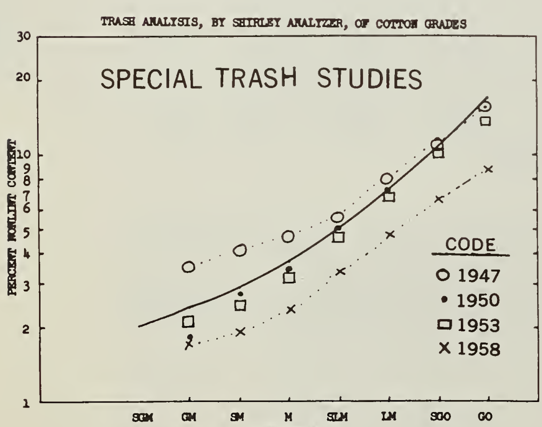


FIGURE 4.--AVERAGES OF NONLINT IN SPECIAL TRASH SURVEYS (WHITE GRADES, 1947-1958).

Shown in relation to standard reference curve. Dotted lines connect data for extreme years.

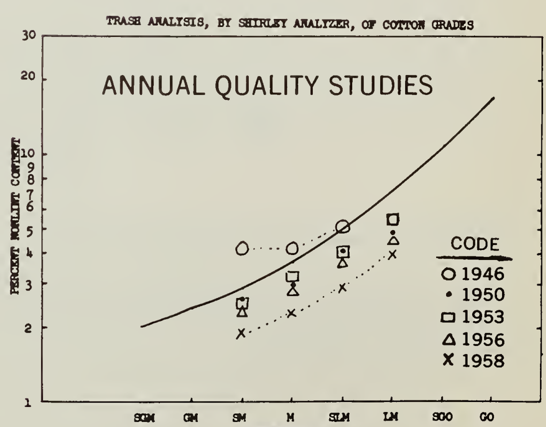


FIGURE 5.--AVERAGES OF NONLINT IN ANNUAL QUALITY STUDIES (WHITE GRADES, 1946-1958).

Shown in relation to standard reference curve. Dotted lines connect data for extreme years.

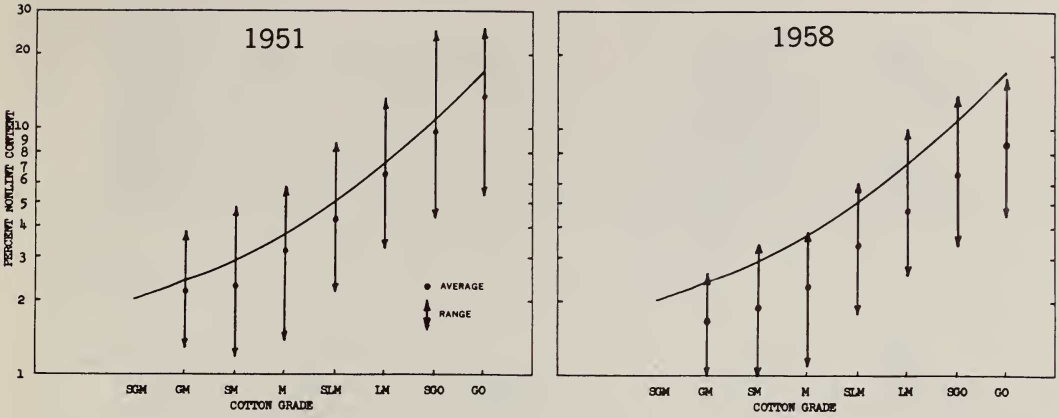


FIGURE 6.--TRASH ANALYSIS FOR PERIODIC SURVEYS OF WHITE GRADES, SHIRLEY ANALYZER NONLINT AVERAGE AND RANGE, 1951 FOR COMPARISON WITH 1958.

NOTE THAT EVEN IN 1951 AVERAGE TRASH CONTENT FOR GRADE SURVEYS WAS LOWER THAN IN STANDARDS BALES (REPRESENTED BY SOLID CURVED LINE). THE RANGE WITHIN EACH GRADE IS WIDE, AS MUCH AS A FOUR TO FIVE GRADE OVERLAP. AVERAGES IN 1958 SHOW LESS TRASH THAN IN 1951 BY AT LEAST A FULL GRADE. THE RANGE IN 1958 SHOWS SLIGHTLY LESS OVERLAP THAN FOR 1951.

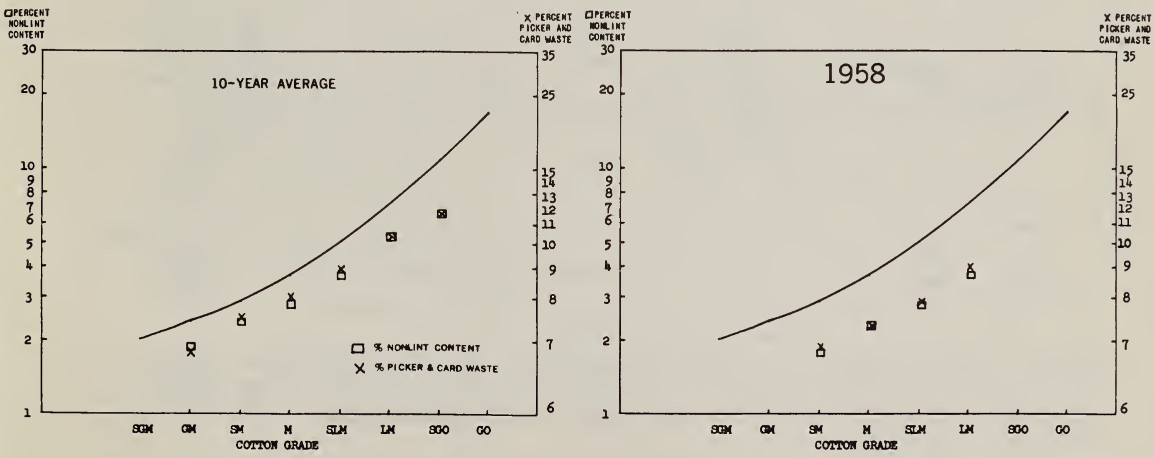


FIGURE 7.--TRASH ANALYZER FOR WHITE GRADES IN ANNUAL QUALITY STUDIES, BOTH SHIRLEY ANALYZER NONLINT AND PICKER AND CARD WASTE, 10-YEAR AVERAGE (1949-1958) AND 1958.

NOTE THAT AVERAGES OF SHIRLEY ANALYZER NONLINT DATA PLUS 5 PERCENT ARE VERY NEARLY EQUIVALENT TO PERCENTAGES OF PICKER AND CARD WASTE FOR EACH GRADE. THUS WHILE THERE IS A WIDE SPREAD AMONG INDIVIDUAL BALES WITHIN EACH GRADE (SEE PREVIOUS FIGURE), SHIRLEY ANALYZER DATA ON THE AVERAGE SHOULD BE A GOOD INDICATION OF WASTE TO BE EXPECTED FOR A MIX THAT USES A SUFFICIENT NUMBER OF BALES. WASTE, HOWEVER MEASURED, IS LESS FOR 1958 THAN FOR PREVIOUS YEARS.

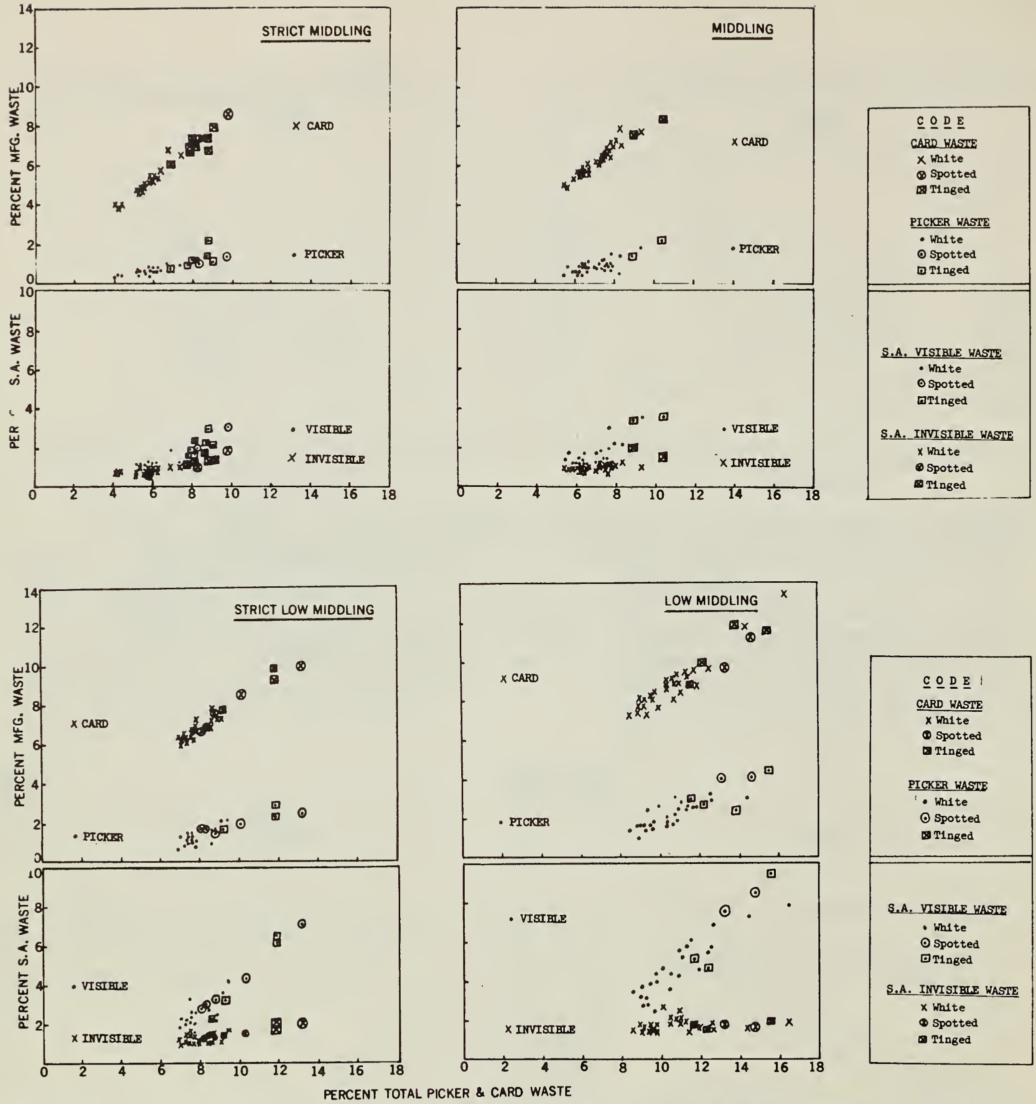


FIGURE 8.--TRASH ANALYSIS OF BALES PURCHASED FOR 1959 GRADE STANDARDS, SHIRLEY ANALYZER NONLINT (VISIBLE AND INVISIBLE) AND FOR MANUFACTURING WASTE (PICKER AND CARD), FOR WHITE, SPOTTED, AND TINGED GRADES STRICT MIDDLING THROUGH LOW MIDDLING.

For the higher grades, as total picker and card waste increases, picker waste increases very little; card waste is the major contributor to the increase. As the grade decreases, both picker and card contribute to the total increase. For Shirley Analyzer waste, the invisible waste remains nearly constant within each grade; the increase in visible waste shows a consistent relationship to the increase in total picker and card waste.

For each grade the picker and the Shirley Analyzer invisible waste show only a slight increase from White to Spotted to Tinged. On the other hand, there is a very considerable increase in card waste and in Shirley Analyzer visible waste. This explains why the classer is not able to assess by visual observation the considerable trash increase in Spotted or Tinged bales that shows up in measurements of total waste, whether by Shirley Analyzer or by manufacturing waste. Shirley Analyzer visible waste is composed of much more than leaf; a large proportion consists of short or tangled fibers, motes, and seed coat fragments, etc.

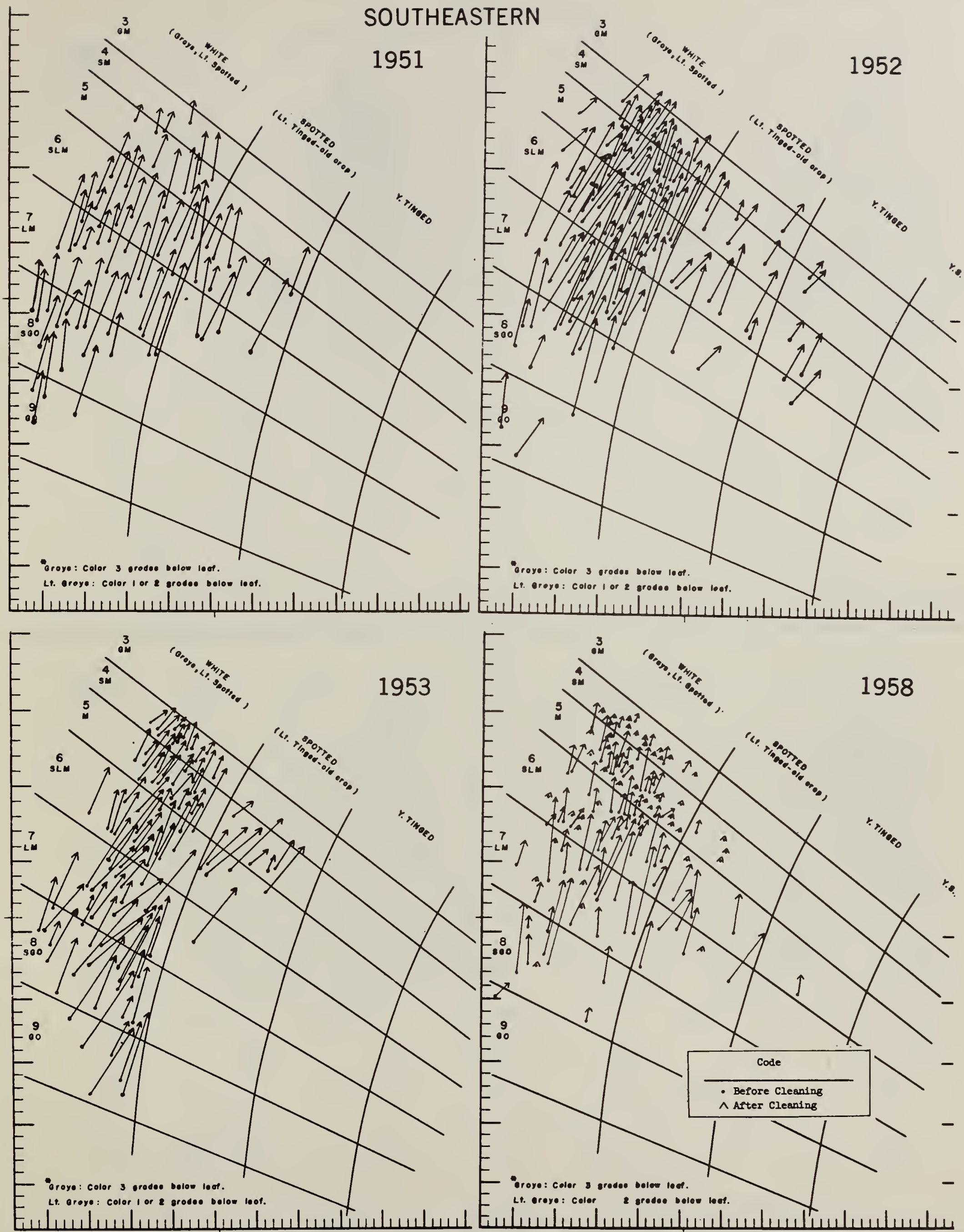


FIGURE 9.--COLOR OF COTTON BEFORE AND AFTER TRASH REMOVAL, SOUTHEASTERN AREA COTTONS, 1951-52-53, and 1958.

FOR MOST SAMPLES IN THESE SPECIAL TRASH SURVEYS, THE 1958 LINT-COLOR-AFTER-CLEANING SHOWS LESS IMPROVEMENT OVER COLOR-BEFORE-CLEANING ON THE SHIRLEY ANALYZER THAN 1951-52-53 COTTONS. SEE SIMILAR RESULTS FOR COTTONS FROM SOUTH CENTRAL, SOUTHWESTERN, AND WESTERN AREAS. UNDOUBTEDLY THIS IS BECAUSE IN 1958 THE COTTON ALREADY HAS HAD MORE CLEANING AT THE GIN THAN WAS CUSTOMARY IN FORMER YEARS. THE AMOUNT OF COLOR CHANGE IS INDICATED BY THE LENGTH OF VECTORS.

SOUTHCENTRAL

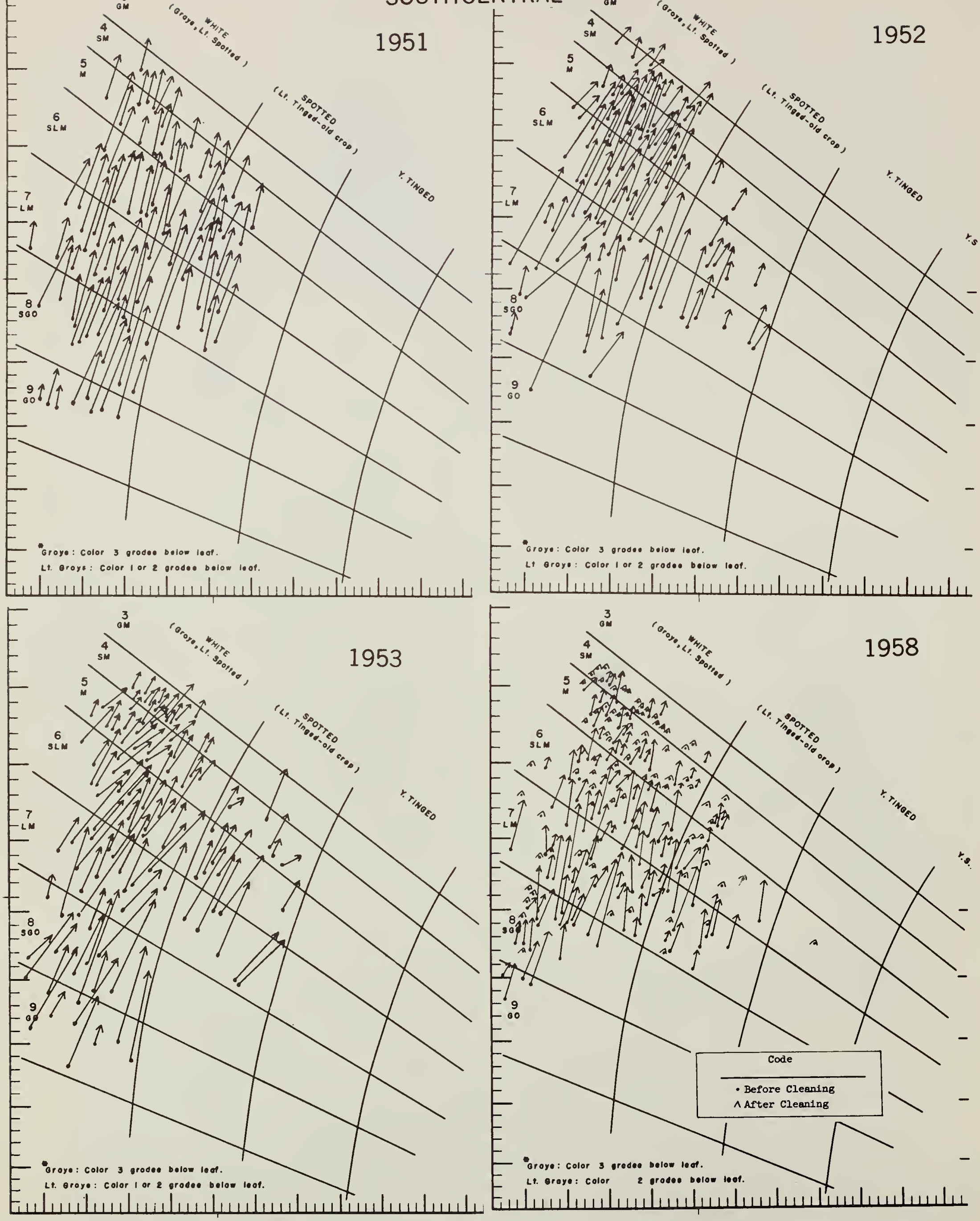


FIGURE 10.--COLOR OF COTTON BEFORE AND AFTER TRASH REMOVAL, SOUTHCENTRAL AREA COTTON, 1951-52-53 AND 1958.

Lint color-after-cleaning for 1958 cottons shows less improvement over color-before-cleaning than for 1951-52-53 cottons.

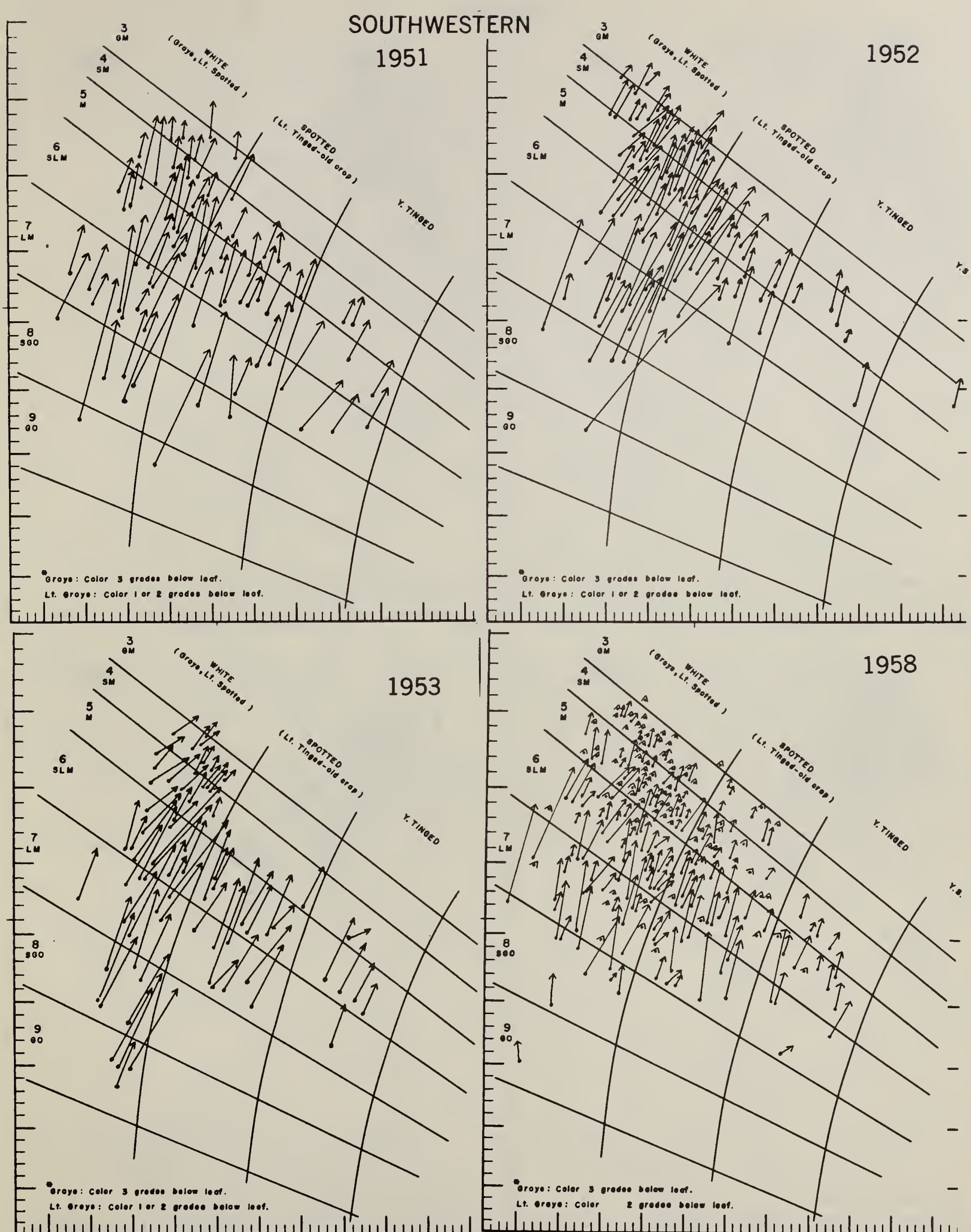


FIGURE 11.--COLOR OF COTTON BEFORE AND AFTER TRASH REMOVAL, SOUTHWESTERN AREA COTTON, 1951-52-53 AND 1958.

Lint color-after-cleaning for 1958 cottons shows less improvement over color-before-cleaning than for 1951-52-53 cottons.

WESTERN

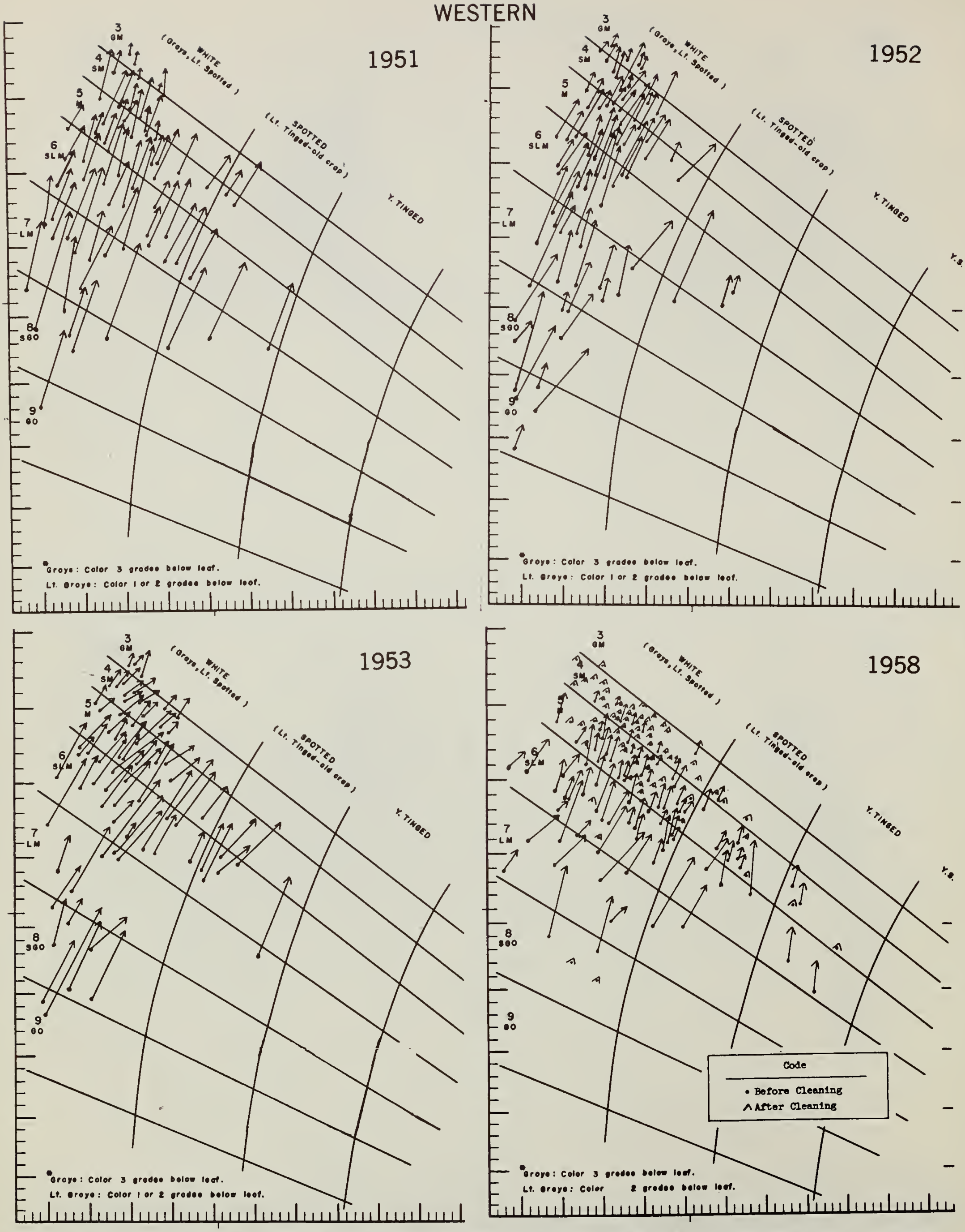


FIGURE 12.--COLOR OF COTTON BEFORE AND AFTER TRASH REMOVAL, WESTERN AREA COTTON, 1951-52-53 AND 1958.

Lint color-after-cleaning for 1958 cottons shows less improvement over color-before-cleaning than for 1951-52-53 cottons.

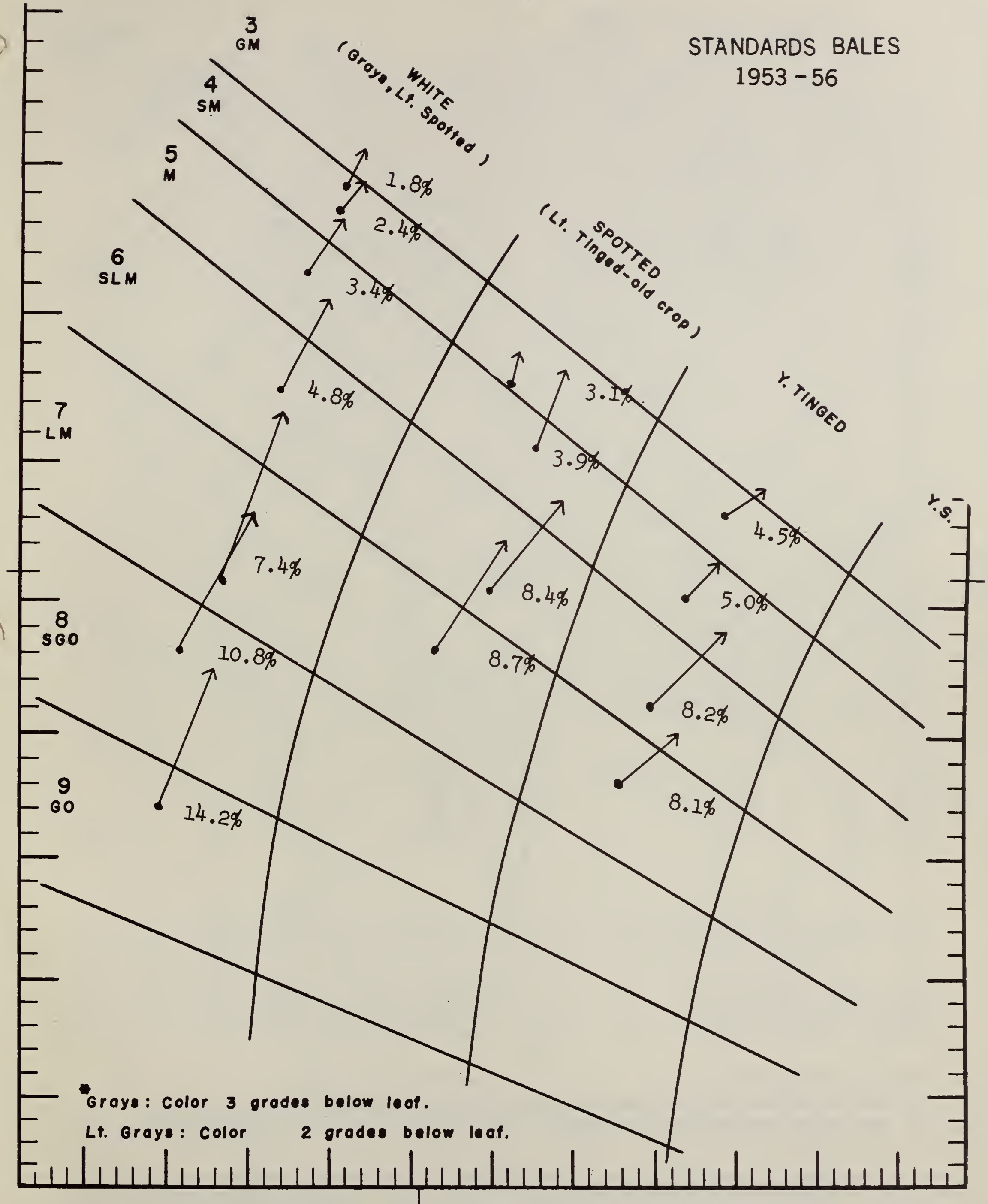


FIGURE 13.--COLOR IMPROVEMENT AND PERCENT NONLINT AFTER CLEANING ON THE SHIRLEY ANALYZER ON BALES USED IN 1953-1956 GRADE STANDARDS.

The amount of color change is indicated by length of vectors; numbers indicate percent nonlint.

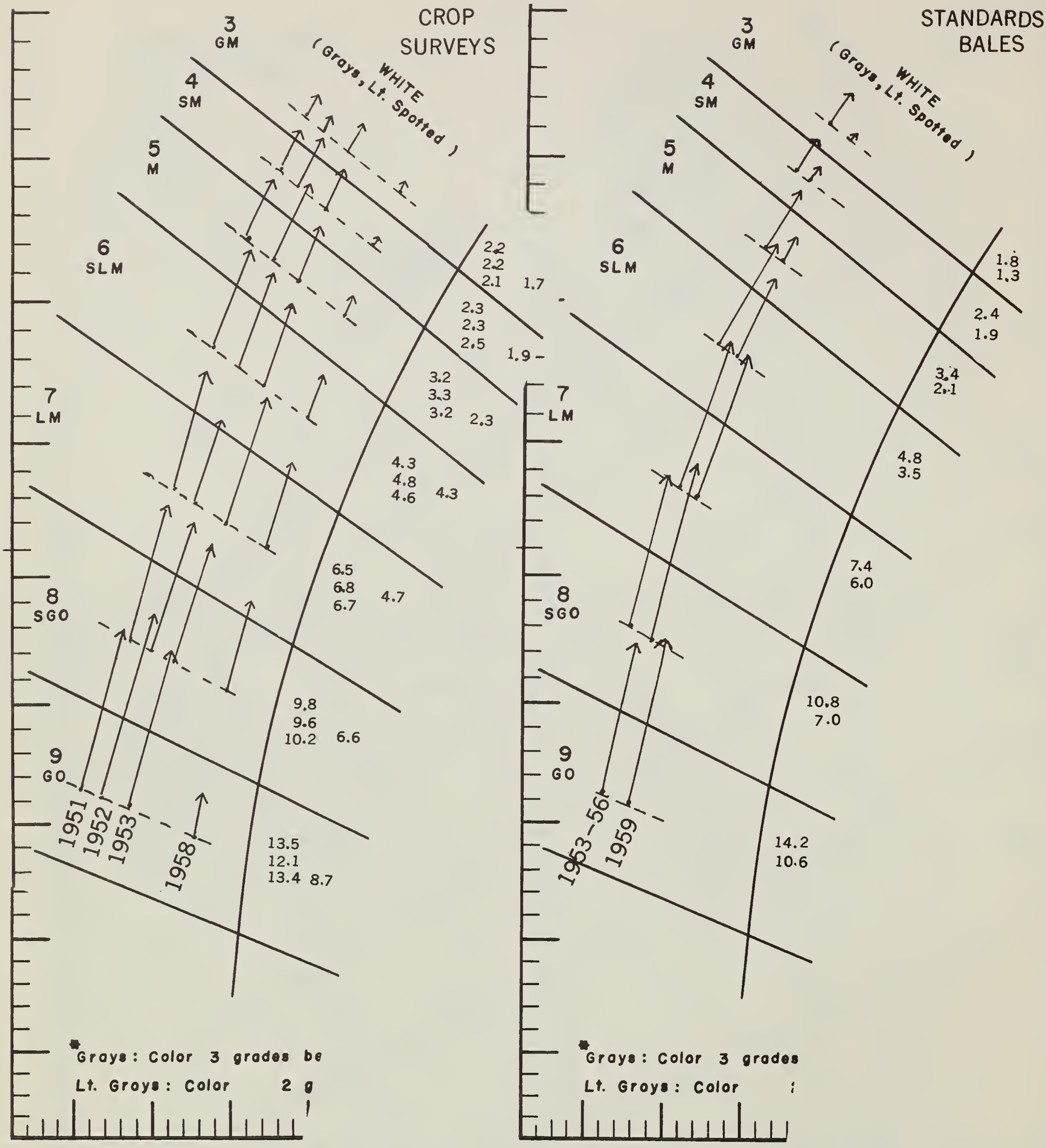
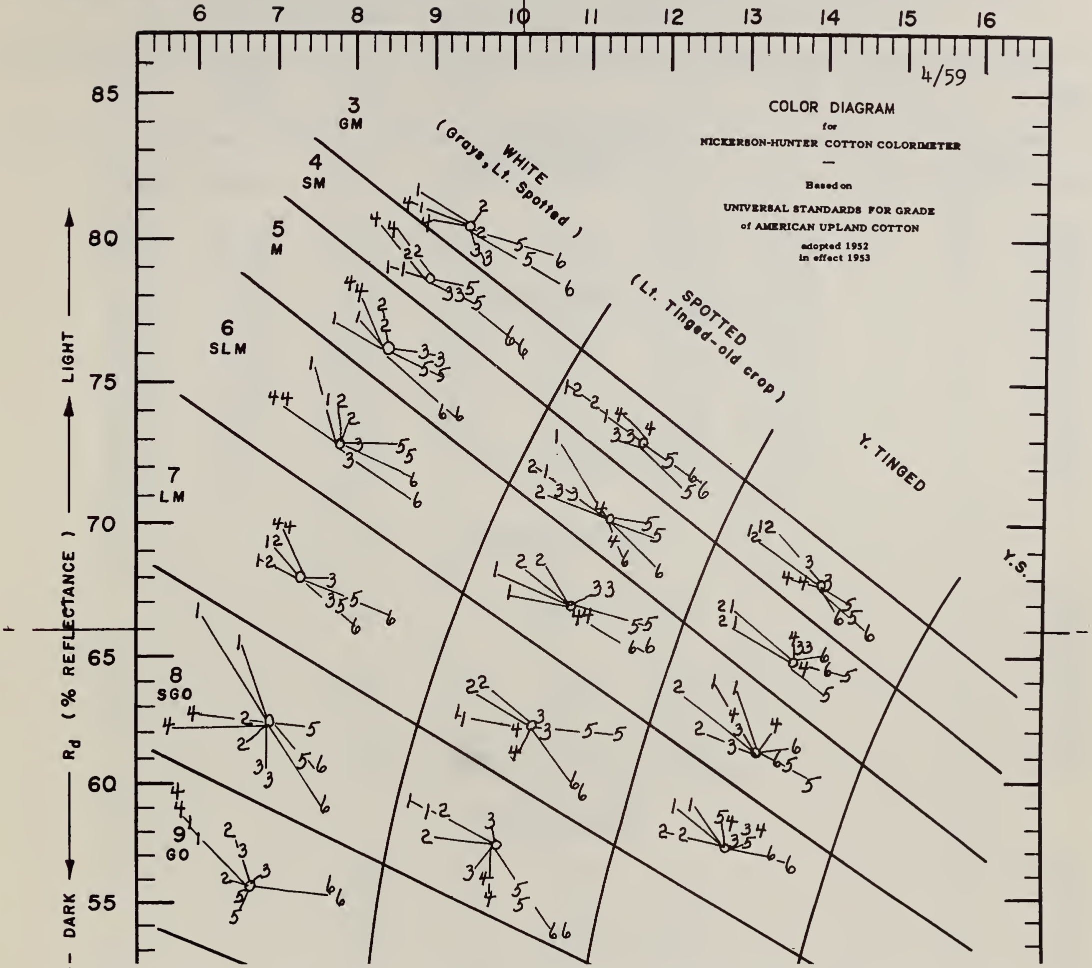


FIGURE 14.--COLOR IMPROVEMENT AND PERCENT NONLINT, AFTER CLEANING ON THE SHIRLEY ANALYZER, FOR WHITE COTTONS IN CROP SURVEYS OF 1951-52-53 and 1958, AND FOR BALES USED IN STANDARDS 1953-56 AND 1959.

THE AMOUNT OF COLOR CHANGE IS ILLUSTRATED BY LENGTH OF VECTORS; NUMBERS INDICATE PERCENT NONLINT.

IN EARLIER YEARS COLOR CHANGE CAUSED BY CLEANING WAS NEARLY ONE FULL GRADE, BUT IN CURRENT CROPS IT AVERAGES MUCH LESS. NOTE THAT THERE IS MUCH LESS DIFFERENCE FOR STANDARDS BALES THAN FOR COTTONS IN THE CROP SURVEYS. THIS IS A RESULT OF THE GREAT CARE TAKEN TO FIND BALES AS NEARLY MATCHING THE OFFICIAL STANDARDS AS POSSIBLE. NOTE THAT WHEN THIS FAILS, IT IS NECESSARY TO MAKE LEAF ADJUSTMENTS IN STANDARDS SAMPLES.

Demonstration Set of Grades
Based on 1958 Cotton Production
Set No. 2



	GM	SM	M	SLM	LM	SGO	GO	4 Sp	5 Sp	6 SP	7 SP	4T	5T	6T	7T
1	20317	20193	20187	20266	20142	20328	20236	20301	20013	20277	20099	19804	20263	19893	20305
2	20016	20038	20186	20249	20139	20150	20056	"	"	"	"	20296	677455	S	S
3	20246	20197	20264	19777	20173	20047	20151	19880	19885	20080	20308	19806	20322	20280	19705
4	20234	20224	20272	20269	20285	20250	20148	"	"	"	"	20298	19440	19364	20319
5	20001	20158	20194	20182	20215	20059	19926	20313	19851	19895	19718	20011	19347	19446	20110
6	20160	20157	20330	19978	20147	20217	20029	"	"	"	"	20011	20316	S	19368

FIGURE 15.--DEMONSTRATION SET OF GRADES IN WHICH AVERAGE COLOR REMAINS AT THE LEVEL OF PRESENT GRADE STANDARDS, WITH ONLY MINOR LEAF ADJUSTMENT.

TRASH AS MEASURED BY SHIRLEY ANALYZER PERCENT NONLINT CONTENT AVERAGES ONE GRADE HIGHER IN THESE SAMPLES THAN IS REQUIRED TO MATCH PRESENT STANDARDS.

SURFACE TRASH NEEDS MAJOR LEAF ADJUSTMENT IN MOST BALES CURRENTLY AVAILABLE AT THE COLOR LEVEL OF PRESENT STANDARDS. IN THIS DEMONSTRATION SET OF SAMPLES THE AVERAGE COLOR IS ON THE LEVEL OF THE PRESENT STANDARDS BUT ONLY MINOR LEAF ADJUSTMENTS HAVE BEEN MADE. SINCE SAMPLES WITH ONLY MINOR ADJUSTMENTS PROVIDE A CLOSER REPRESENTATION OF COTTONS IN CURRENT MARKETS THAN SAMPLES THAT REQUIRE MAJOR ADJUSTMENTS, THIS DEMONSTRATION SET MAY PROVIDE A BASIS FOR CONSIDERATION OF A PRACTICAL REVISION OF THE GRADE STANDARDS. (THE SGO SPOTTED INSERTED ON THE CHART IS FOR STUDY PURPOSES ONLY.)

Table 1.--Trash analysis (Shirley Analyzer nonlint content) of bales used in cotton grade standards and guides, 1936-1959 1/

Year	SGM 2	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
				White Grades				
Std.curve 2/	2.0	2.4	2.9	3.7	5.1	7.6	11.0	17.0
1936		2.9	3.6	3.8	5.4	8.1	11.0	18.6
1946		2.4	3.5	3.7	5.1	7.7	11.2	15.2
1950		2.4	3.1	3.6	4.7	7.6	11.7	13.5
1952-3		1.8	2.7	3.5	5.2	8.1	11.5	15.3
1954		1.7	2.6	3.5	4.5	8.0	11.8	13.0
1955		1.8	2.5	2.8	4.5	7.4	11.3	14.8
1956		1.8	2.3	3.1	4.7	7.3	10.7	13.3
1957		1.9	2.4	3.3	4.5	6.1	7.5	13.6
1958		1.9	2.4	3.1	3.9	5.7	7.6	10.8
1959		1.3	1.9	2.1	3.5	6.0	7.0	10.6
				Spotted Grades				
1952-3			3.1	4.4	5.8	8.1		
1954								
1955								
1956			2.4	3.5	6.7	8.4		
1957			3.0	4.3	6.3	8.3		
1958			2.7	4.9	5.9	10.1		
1959			2.7	4.0	6.4	6.1		
				Tinged Grades				
1952-3			3.9	4.3	7.9	8.3		
1954			4.3	5.0	8.2	7.5		
1955			3.7	5.6	6.5	6.8		
1956			3.6	5.1	9.5	8.6		
1957			3.2	7.3	10.0	7.7		
1958			3.5	5.3	8.2	6.1		
1959			1.9	5.7	6.0	6.9		

1/ From bales purchased for use in making 1959 standards boxes.
2/ From smoothed curve based on 1936, 1946 standards, and used since then as reference curve for nonlint in cotton grade standards.

Table 2.--Trash analysis (Shirley Analyzer nonlint content) of grade survey samples, by years for which special trash surveys were made: 1947, 1951-53, 1958

Year	Percent Nonlint by Grades							
	SGM 2	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
				White Grades				
1947		3.5	4.0	4.6	5.5	7.8	11.0	15.3
1951	1.6	2.2	2.3	3.2	4.3	6.5	9.8	13.5
1952		2.2	2.3	3.3	4.8	6.8	9.6	12.1
1953		2.1	2.5	3.2	4.6	6.7	10.2	13.4
1958		1.7	1.9	2.3	3.4	4.7	6.6	8.7
				Light Spotted Grades				
1947		5.1	4.3	5.5	7.2	10.2		
1951		2.7	3.5	4.3	5.8	7.3		
1952		2.4	3.4	4.4	6.4	8.2		
1953		2.3	3.2	4.4	5.9	8.6		
1958		1.8	2.6	3.1	4.3	6.0		
				Spotted Grades				
1947		4.4	5.3	5.2	6.7	9.9		
1951		2.3	3.7	4.5	6.1	10.2		
1952		1.4 1/	3.5	4.9	6.6	9.5		
1953		3.0	3.5	4.5	6.6	8.6		
1958		1.9	3.2	3.6	5.0	7.2		
				Tinged Grades				
1947			5.5	6.6	8.2	9.3		
1951			5.0	6.0	6.5	10.0		
1952		2.3	5.0	5.4	7.3	9.2		
1953				4.9	6.5	9.9		
1958			3.8	4.7	5.9	7.7		
				Yellow Stained Grades				
1947			6.4	8.3	11.3			
1951				7.6	7.5			
1952			5.7	6.8				
1953				11.9 1/				
1958								
				+ White Grades				
1947				4.0	5.4	7.6	10.7	11.4
1951				3.1	4.2	6.4	8.8	
1952				2.7	4.4	6.4	10.4	17.1
1953				3.0	4.3	5.9	9.6	13.3
1958				2.4	3.3	4.5	6.5	10.2
				Light Gray Grades				
1947			4.9	5.1				
1951		2.0	2.8	4.1	4.9			
1952		2.7	3.1	4.0	6.0			
1953		3.4	3.4	4.3	6.4			
1958		1.9	2.1	3.0	3.8			
				Gray Grades				
1947			4.4	6.0	7.2			
1951			3.6	3.9	5.2			
1952			2.7	3.7	4.5			
1953		3.0	3.4	3.2	5.4			
1958		1.9	2.3	3.2	4.4			

1/ One sample only.

Table 3.--Trash analysis (Shirley Analyzer nonlint content) of samples, by years, from cotton quality studies published annually since 1946

Year	Percent Nonlint by Grades						
	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
			White Grades				
1946		4.2	4.2	5.2			
1947		3.2	3.7	4.8	5.8		
1948	3.6	3.7	3.8	4.8	5.9	10.2	
1949	2.6	3.3	3.8	4.7	6.0		
1950		2.6	3.0	4.1	4.9	7.8	
1951		2.5	3.2	3.7	6.6		
1952	1.5	2.6	3.2	4.3	5.9	5.4	
1953	1.3	2.5	3.2	4.1	5.5		
1954	2.2	2.4	3.2	4.0	5.5		
1955		2.4	3.1	3.8	5.7		
1956	1.8	2.3	2.8	3.7	4.6		
1957	1.1	2.1	2.6	3.3	4.7	6.7	
1958		1.9	2.3	2.9	4.0		
			Light Spotted Grades				
1946		3.9					
1947		4.2	3.5				
1948		4.1	3.7				
1949		3.8	4.3				
1950		3.0	4.1	5.9			
1951		3.0	4.2	4.0			
1952		3.8	4.5	9.0			
1953		2.0	3.7				
1954		3.1	4.0				
1955		2.0	3.5	4.1			
1956		2.8	3.7	6.2			
1957		2.6	3.0	4.2	4.9		
1958		2.3	3.2	3.9			
			Spotted Grades				
1946							
1947		4.0	4.9				
1948		4.3	4.6	8.0			
1949		3.8	4.8				
1950		3.0	4.2	9.1	10.3		
1951		2.8	5.3	7.3	9.6		
1952		3.2	3.4	9.0			
1953							
1954							
1955							
1956			4.0				
1957			2.9	4.3	6.0		
1958							
			+ White Grades				
1946			4.3	4.4	6.3		
1947			3.4	4.3			
1948			3.9	4.4	5.0		
1949			3.6				
1950			2.8	3.5	7.0		
1951			2.7	4.1	5.0	6.8	
1952			2.7	3.7	4.5		
1953			2.8	4.0	5.1		
1954			3.0				
1955							
1956							
1957			2.2	3.8	4.2		
1958			2.3	3.6	3.9		

Table 4.--Trash analysis (picker and card waste) of samples, by years, from <u>cotton quality studies</u> published annually since 1946

Year	Percent Picker and Card Waste						
	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
			White Grades				
1946		8.5	8.6	9.7			
1947		7.6	8.5	9.4	12.4		
1948	8.6	7.9	7.8	9.0	10.0	15.6	
1949	7.2	8.7	9.2	10.1	11.7		
1950		7.9	8.1	9.3	11.3		
1951		7.6	8.1	8.9	11.6	12.8	
1952	5.0	6.7	7.2	8.5	9.9		
1953	7.8	6.6	7.2	8.1	9.7	10.0	
1954	6.6	6.8	7.5	8.5	9.6		
1955		7.7	8.2	9.0	11.2		
1956	7.8	8.0	8.1	9.2	10.4		
1957	7.3	7.7	7.9	8.8	9.8	12.5	
1958		6.9	7.4	7.9	9.8		
			Light Spotted Grades				
1946		9.1					
1947		10.3	8.3				
1948		8.3	7.8				
1949		9.7	10.1				
1950		8.5	9.7	13.4			
1951		8.8	10.1	8.7			
1952		8.2	8.7	13.8			
1953		6.7	8.5				
1954		7.4	8.7				
1955		7.7	9.5	10.1			
1956		8.5	9.2	12.1			
1957		8.6	8.8	9.8	11.2		
1958		8.4	8.5	9.4			
			Spotted Grades				
1946							
1947		10.0	9.1				
1948		7.6	9.0	11.6			
1949		8.8	11.4				
1950		8.4	10.5	14.3	17.1		
1951		7.6	9.8	11.7	14.7		
1952		7.8	9.0	12.9			
1953							
1954							
1955							
1956			9.8				
1957			9.5	10.1	12.1		
1958							
			+ White Grades				
1946			8.1	9.0	11.1		
1947			8.0	8.8			
1948			7.9	8.5	7.5		
1949			9.3	9.7	11.4		
1950			7.8	8.5	13.1		
1951			7.6	9.1	10.8	11.6	
1952			6.4	7.4	9.4		
1953			6.6	7.6	9.2		
1954			7.2				
1955							
1956							
1957			7.7	9.2	4.8		
1958			6.4	7.7	8.1		

Table 5.--Change 1/ in color, by grades, before and after cleaning on the Shirley Analyzer, for cottons in special grade-trash surveys of 1951-52-53 and 1958, and in cottons bought for use in grade standards. 2/

Year	Area	GM	SM	M	SLM	LM	SGO	GO	4Sp	5Sp	6Sp	7Sp	4T	5T	6T	7T
		Grade-Trash Surveys														
1951	U.S.	4	9	13	20	23	27	31		14	18	25		10	15	21
1952	"	3	10	16	19	17	26	37	13	12	14	26		10	15	6
1953	"	6	8	12	17	25	23	29		11	18	27		9	18	16
1958	"	0	2	4	9	17	17	8	3	3	9	16		5	8	19
1951	S.E.		8	13	19	23	20	22			18	28				
	S.C.		11	13	23	21	28	24		14	15	23				
	S.W.		9	13	19	23	29	52*		14	18	20		10	15	21
	W.	4	9	14	19	25	29	30*		16	20*	29				
1952	S.E.		11	16	20	22	24	24	13	14	18	23		10	13	6
	S.C.		8	16	20	22	25	53*		9	10	18				
	S.W.	7	11	20	22	11	36	47*		14	18	26		11	16	
	W.	5	11	12	14	12	19	23			10	36				
1953	S.E.		8	12	17	21	21	26		9	22	25				
	S.C.		7	11	16	23	22	26		10	16	26				
	S.W.		8	12	18	29	29	29		15	18	25		9	18	16
	W.	6	8	11	18	26	20	35			18	32				
1958	S.E.		1	5	9	16	17	8		1	12	17			8	22
	S.C.		2	3	8	11	13	12		3	4	11			5	
	S.W.	0	2	4	10	12	25	4	4	3	10	15		7	8	16
	W.	0	1	4	10	20	12		2	5	10	21		4	12	
		Standards Bales														
1953-56	—	8	9	13	22	28	30	29	7	19	24	26	10	12	20	15
1959	—	6	9	3	16	29	34	32					5	8	18	29

* One sample only.

1/ Units are arbitrary (based on vector lengths for data similar to those plotted in figures 9 to 12).

2/ It should be noted that for bales bought for the standards, whenever there is too little trash to match the officially adopted standards, trash particles are added to the surface of the cotton. Great care is taken to find bales as nearly matching the official standards for color, leaf, and preparation as possible. When this is not successful, leaf adjustments must be made.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COTTON GRADE STUDIES

COLOR CHANGE IN STORAGE

A preliminary report of 1956 grade standards in storage since 1956 under several conditions of temperature and humidity, prepared for use at the 1959 Universal Grade Standards Conference, Washington, D. C., May 25-27, 1959

by

Dorothy Nickerson
Josephine J. Tomaszewski
Standardization Section
Standards and Testing Branch

* * * * * * *
* * * * *
* * *
*

Administrative Use

Washington 25, D. C.

May 1959
No. 4 of 4 reports

COLOR CHANGE OF COTTON IN STORAGE

As promised at the 1956 Universal Grade Standards Conference, sets of samples from bales used in the grade boxes passed at the conference were placed in storage at various controlled conditions of temperature and humidity.

After one year of storage the results were so definite that they were reported and published in Textile Research, June 1958. A reprint of this paper is attached.

Color measurements were again made on the same samples in the spring of 1958, and finally in April of 1959, just a few weeks before the 1959 conference. There has not been time to prepare new diagrams for all of the conditions used in the test and reported on in the Textile Research paper. We have, however, prepared one chart, included in this report, page number ii , that shows the three-year change for samples held under the following four conditions of temperature and humidity: 0°; 50° F., 50% R.H.; 100° F., 50% R.H.; and 100° F., 85+% R.H. Samples from these stored sets will be available for inspection at the conference.

After one year of storage it was recommended (page 496 of the attached report) that so little change in color had occurred under 50° F., 50% R.H. as compared to the other conditions that this would provide a good practical target for conditions under which we should store our standards boxes between conferences.

Results of the three-year test show greater changes at all conditions, erratic but small changes in cottons held under 0°, and under 50° F., 50% R.H., large changes at 100° F., 50% R.H., and very large changes at 100° F., 85+% R.H. On this basis it is concluded that the conditions of approximately 50° F., 50% R.H. now installed in a storage room for standards to be passed at this conference will be used until such time as a final evaluation is made of all of the most recent results.

Meanwhile, as a matter of information regarding the effect on spinning quality of these changes in color, we are conducting fiber, spinning, and finishing tests before and after storage at 50°F., 50% R.H., at 100° F., 50% R.H., and at 100° F., 85+% R.H., on cottons from 28 bales used in grade standards put up in 1958. Evaluation of results of these tests will be made and reported as soon as they are completed, probably some time during 1960.

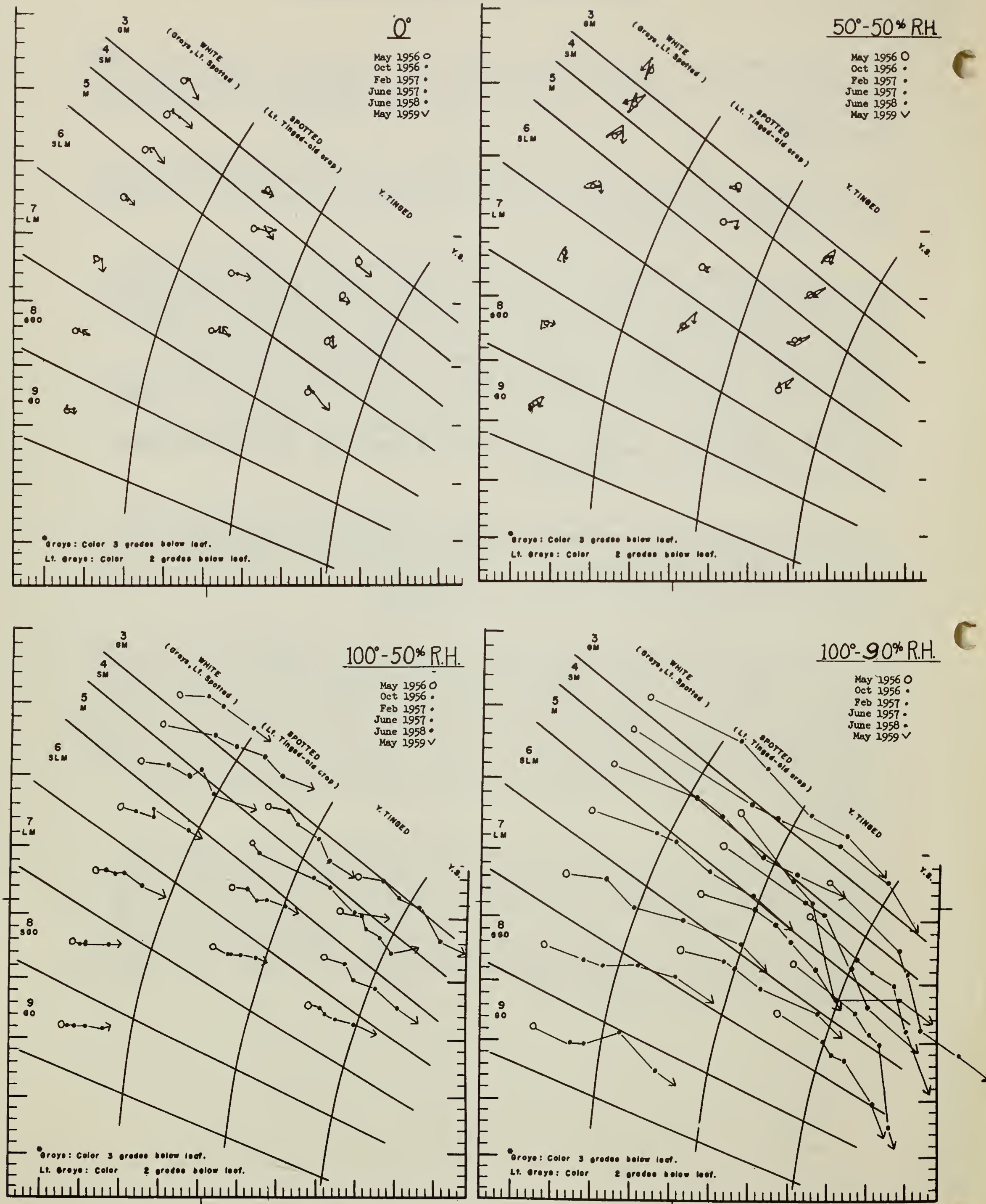


FIGURE 16.--THREE-YEAR COLOR CHANGE FOR SAMPLES UNDER FOUR CONDITIONS OF TEMPERATURE AND HUMIDITY: 0°; 50°F., 50% R.H.; 100°F., 50% R.H.; 100°F., 90% R.H.

Reprinted from Textile Research Journal, Vol. XXVIII, No. 6, June, 1958
Printed in U. S. A.

Color Change in Raw Cotton Related to Conditions of Storage

Dorothy Nickerson and Josephine J. Tomaszewski

United States Department of Agriculture, Agricultural Marketing Service, Washington, D. C.

Introduction

Since color is one of the measurable grade factors on which the quality of raw cotton is judged, there is considerable interest in knowing the degree of color change associated with different conditions of storage. Samples classed White when put into storage may be classed Spotted when withdrawn, or cottons put into storage as Spotted may come out as Tinged. For the general case, such facts are recognized [4, 5], but for specific cases, especially when the financial consideration involved may be large, the question recurs regarding the extent to which this reflects a real change.

Standards for grade will themselves change, a fact recognized for many years as a serious problem in standardization and reported elsewhere [6, 7]. But very little has been reported that is based on storage under a planned series of known conditions of humidity and temperature. Enough has been done to indicate that a combination of high temperature and high humidity will cause more color change in a given period than a combination of high temperature and low humidity, and that both combinations will cause more change than those involving moderate temperatures and humidities. Cottons held under refrigeration seem to show little or no color change. But no information has been available for specifying optimum conditions of temperature and humidity under which there would be a minimum of cotton color change. If it were financially feasible to meet such conditions, it would be a matter of very practical importance to all who now store cottons. If it should prove difficult or expensive to meet such specifications, this information would still be of great practical value even if its use were limited to storage of cotton standards after their adoption, for it would save a great deal of time, money, and argument relating to their continued validity and use.

At the 1956 Universal Cotton Grade Standards Conference it was pointed out that studies made on returned standards showed that color deteriorates more rapidly in use than had been supposed. This lowering of color through use (the samples get dusty and therefore measure darker), plus the yellowing that occurs during normal conditions of storage, all pointed toward the desirability of establishing a validity period on standards at 12 months. Universal grade standards conferences usually are held every

three years. Since preliminary results of laboratory studies indicated that cottons held under refrigeration changed very little in comparison to changes in cotton held at other more usual conditions of room storage, it seemed feasible to pass extra boxes at the 1956 conference and place enough of them in refrigeration to issue a new set annually to each signatory between conferences. While preliminary refrigeration studies were not carried out under controlled conditions, results seemed so favorable that at the 1956 conference storage of 1956 standards was proposed, and it was promised that during the three years before the next scheduled conference (1959) a controlled experiment would be made.

The study now reported was initiated immediately following this 1956 conference, and while it will be continued for the promised three-year period (so that the extent of any further change in that time may be known), results for the first year have proved so decisive and so useful that they are reported, for they seem to provide sufficient basis for setting specifications of temperature and humidity for holding cotton in storage to prevent or retard its color change.

Conditions of Storage

Through Dr. H. C. Diehl, Director of the Refrigeration Research Foundation, a series of storage chambers were located at Beltsville, Maryland and Experiment, Georgia, in which other tests were being processed. Through the cooperation of Dr. Harold T. Cook, Biological Sciences Branch of the Agricultural Marketing Service at Beltsville, and Dr. J. G. Woodroof of the Food Processing Division of the Georgia Experiment Station at Experiment, Georgia, space was made available in these chambers to store sets of cotton samples for periods up to three years under the following conditions:

Temperature, F.	Relative humidity, %
* 0°	H
22°	H
32°	H
38°	H
40°	H
45°	H
50°	H, 85%
50°	L, 50%
60°	H
70°	L, 50%
* 70°	H, 85%–90%
85°	H
*100°	H, 90%
*100°	L, 50%

Asterisks indicate storage at Experiment, Georgia; the other conditions are those used at Beltsville, Maryland. Except as noted humidity was uncontrolled and is marked H (high); the L (low) humidity in each case was held at 50%. In most chambers fruits and vegetables were being tested; some were even rotting, so that storage conditions were not always entirely suitable for cotton. However, use was made of what was available.

Material Stored and Method of Color Description

There are 24 grades of upland cotton now in effect [1]. Of these, 11 of the White and Tinged grades are represented in physical form by a 12-sample official box and a 6-sample guide box. In addition, 4 Spotted grades are represented in physical form by 6-sample field trial boxes. Following the 1956 conference, sufficient sets of these 15 grades were set aside to use in this study.

Samples from 6 bales are used in each White grade, 1 sample from each in the 6-sample box and 2 in the 12-sample box. The bales in each grade come from at least four different cotton growing areas: bales 1 and 2 come from the South Central area, bale 3 from the Southeast, bale 4 from the West, and bales 5 and 6 from the Southwest. In the Spotted and Tinged grades there may be no more than 3 bales used, these being selected to represent the color range of the box from the whitest to the yellowest samples.

Figure 1 is a diagram (based on the 1953 cotton grade standards) [6] used on the Nickerson-Hunter Cotton Colorimeter on which the measurements reported from this test were made. To understand this diagram one should know that while color has three dimensions (hue, lightness, and chroma), the hue for cotton is so nearly constant that measurements of lightness and chroma are sufficient to define the color of cotton grades, a fact that is convenient, since it allows use of the two-dimensional diagram shown. The Hunter scales used in this instrument indicate in a vertical direction the percent reflectance (R_d), which is a measure of the lightness of a sample, and in a horizontal direction Hunter's $+b$ which, for this instrument, indicates the degree of yellowness (with hue constant) and thus provides a measure of chroma. High grades are toward the top of the diagram, low grades toward the bottom; gray colors are toward the left, and yellow tinged or

stained colors are toward the right. The original of this diagram is made in a size that fits over the diagram on the instrument, so that indicated points may be plotted directly.

On this diagram the color range of each of the bales used in the 1956 standards and Spotted boxes is shown in the odd-shaped numbered enclosures. As may be seen, there is some overlapping of color in the Good Middling bales into Strict Middling (for it was not possible in all cases in 1956 to obtain bales to represent a full color step above Strict Middling), but otherwise there is no overlapping. The number in each enclosure indicates the bale position in the box, 1 to 6.

Samples in the test were individually measured for color at the beginning of the storage period and each time they were withdrawn, but in Figure 1 the range is shown for each bale. This range may represent measurements on as many as 1000 or more samples from each bale.

Color After Storage

So many samples are involved in each set that in order to show the overall picture, results are averaged for each grade and are shown on diagrams in Figures 2–12. Identification of the scales on the diagrams is omitted to save space; they are identical to those in Figure 1, which is reproduced in a large enough size to provide details. The small circle at the center of each grade represents its average color, and differences that develop during the various stor-

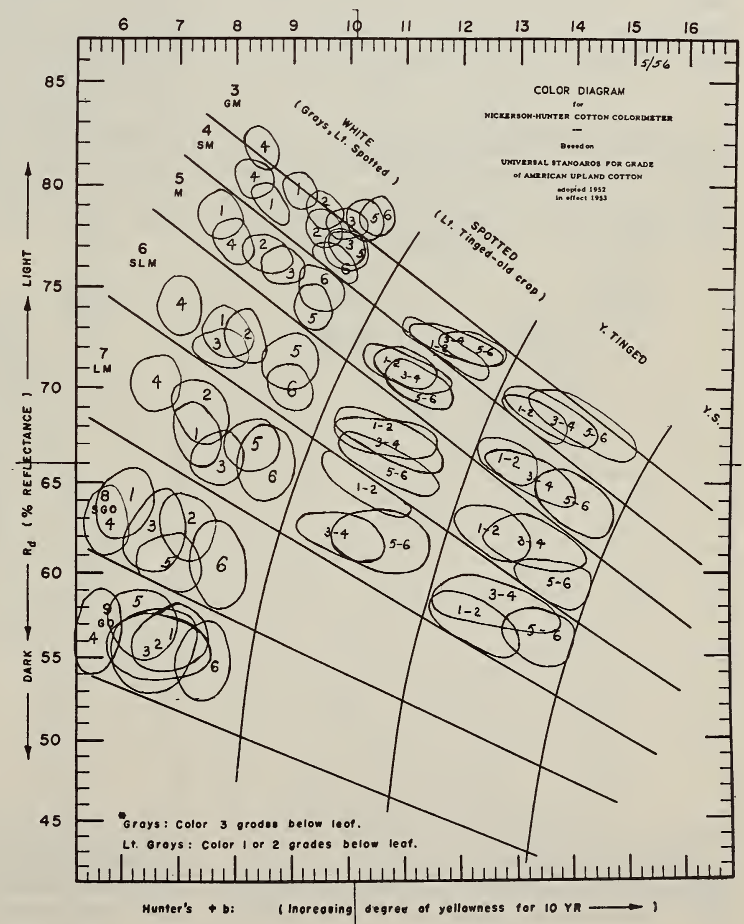


Fig. 1. Color diagram for the universal cotton grade standards. The color range of bales used in the 1956 standards and spotted guides is shown in the odd-shaped numbered enclosures. The number in each enclosure indicates the bale position in the standards box.

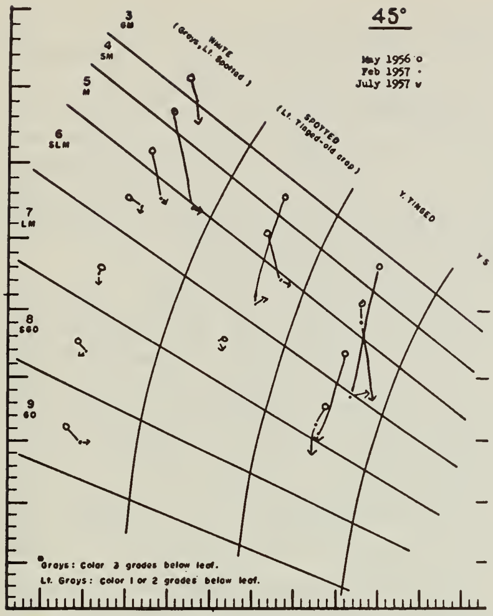


Fig. 7. Color change for storage at 45° F. is a slight yellowing, but chiefly a darkening caused by microbiological action.

is very considerable, the White grades yellowing into Spotted, the upper grades even into Tinged, with a darkening as well as yellowing for the Spotted and Tinged samples that were stored. Results shown in Figures 10, 11, and 12 are for storage at 50°, 70°, and 100° at two humidities, one held at 50%, the other uncontrolled, which measured about 85%–90%.

At 50°, Figure 10, little or no color change occurred in samples stored under low humidity, but change did occur in samples stored at high humidity. This change included some yellowing even within the first 9 months, but much of the change, particularly the darkening in the Spotted and Tinged grades, was undoubtedly caused by the *Penicillium.*

At 70° storage, Figure 11, there was a noticeable amount of yellowing at 50% humidity, especially in the higher grades, and a very great change at 85% humidity both in yellowing and in darkening of color. The change was considerable in the first 6 months of storage, and has continued since then.

At 100° storage, Figure 12, under 50% humidity, a noticeable yellowing occurred during the first 6 months that has continued since then. Under 90% humidity the color change was greater and occurred

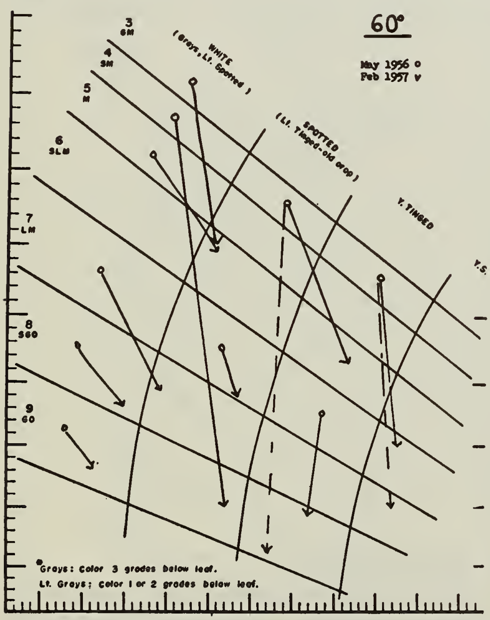


Fig. 8. Color change for storage at 60° F. is a severe darkening caused chiefly by high *Penicillium* contamination.

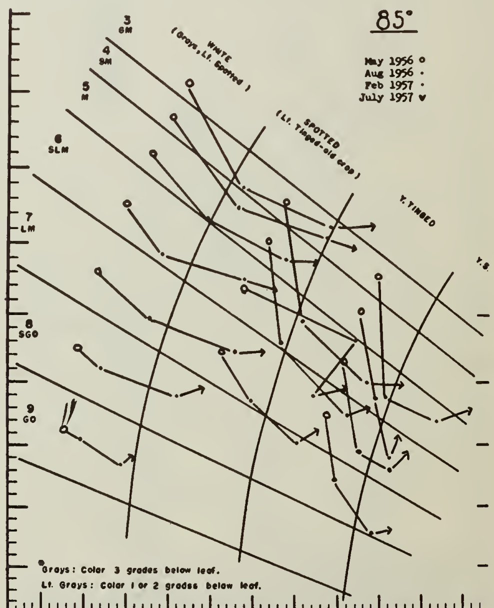


Fig. 9. Color change for storage at 85° F. is a considerable yellowing even after only 3 months of storage, with some darkening caused by microbiological action.

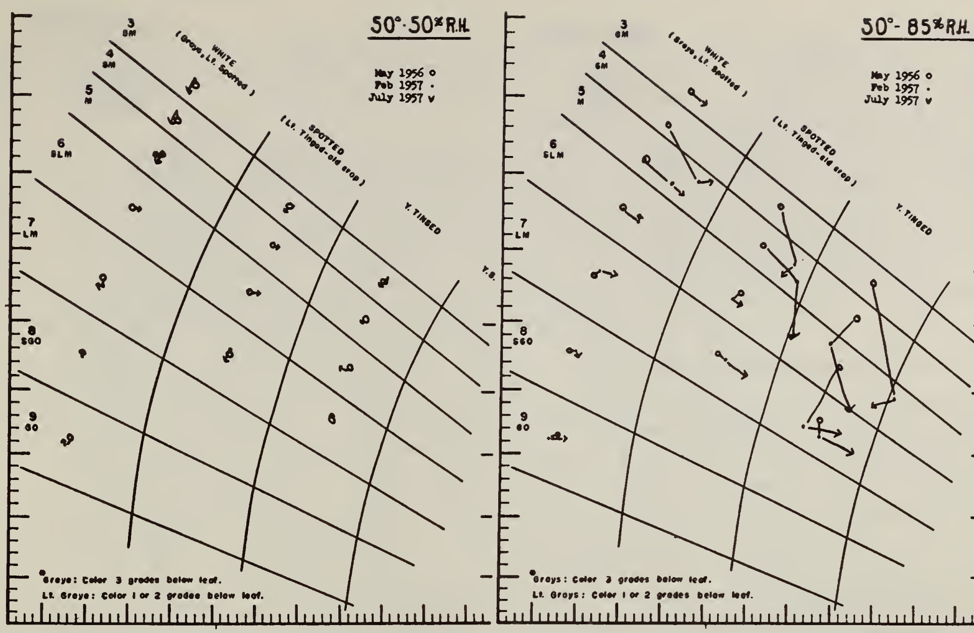


Fig. 10. Color change for storage at 50° F. At 50% relative humidity no significant change occurred in 1 yr., but at 85% relative humidity a significant yellowing occurred, greater for high grades than for low, with considerable darkening caused by microbiological action.

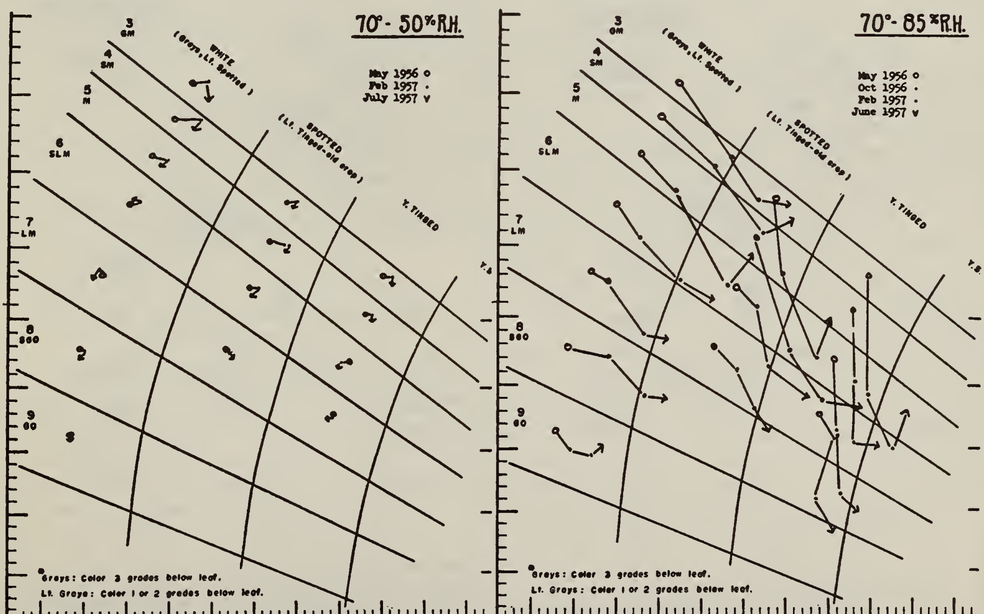


Fig. 11. Color change for storage at 70° F. At 50% relative humidity a slight yellowing occurred in the higher grades; a slight darkening was caused by microbiological action. At 85% relative humidity the color change was highly significant, with more yellowing in high grades than in low, and there was considerable darkening because of microbiological action.

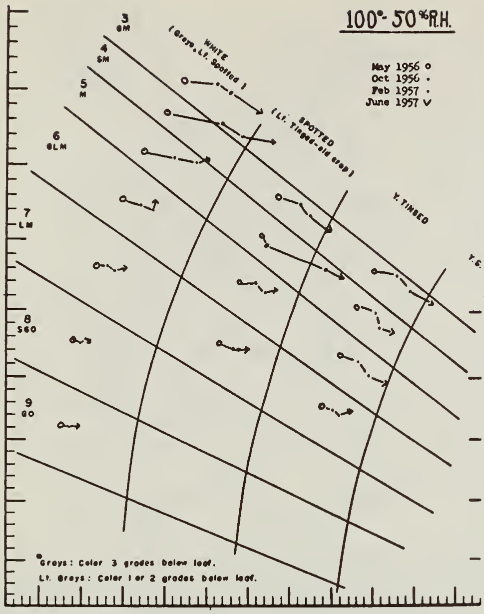


Fig. 12. Color change for storage at 100° F. At 50% relative humidity considerable yellowing occurred, more at high grades than at low; at 90% relative humidity there was an extraordinary amount of yellowing but little darkening.

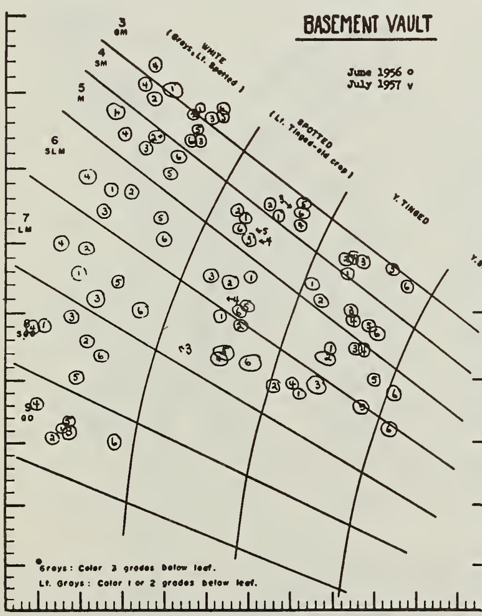


Fig. 13. Color change of individual samples of standards stored in basement vault and in classing room. In the first year no significant change occurred during storage in the vault, but significant though small changes occurred during storage in the classing room, particularly in the higher grades.

more rapidly. At 100° little darkening took place even at high humidity, since the 100° temperature quite evidently inhibited the growth of *Penicillium* mold.

The data in Figures 2 through 12 represent averages for each grade shown. In Figure 13 individual results are shown for two sets of standards, one stored in the basement vault in which extra standards are being stored between the 1956 and 1959 conferences and the other stored in the sixth floor classing room of the Cotton Division, where standards are made and passed. The bale position number for samples in each grade is circled when there was no measurable color change. Change in color is indicated by an arrow connected to the sample number. There are few and very short arrows on the diagram representing storage in the basement vault, but there are many changes indicated on the diagram representing samples stored in the classing room, and for the high grades these are significant changes for 1 year of storage.

Samples in the White grades represent different areas of growth, and since the question often is asked whether samples from one area change either more or more rapidly than samples from another area, a study was made of the differences in yellowness that developed under the several storage conditions for each sample by bale position number. The results of this study are shown in Figure 14. While it is not always true, and the differences are not always great, there does seem to be a tendency for the bale in No. 4 position to change more than those in other positions. Number 4 is the Western bale, usually the whitest bale in each box when the grades are first assembled.

Dollar Values Involved in Color and Grade Changes

The dollar values involved in changes that occur during storage are sometimes very considerable. To illustrate this in a manner in which price differences may be related directly to the size of grade differences involved in the various storage tests, Figure 15 shows prices for each grade posted on a color diagram similar to the one used in Figures 2–13. Prices for 500-lb. bales, based on 1956–57 average spot quotations for 14 markets for $1\frac{1}{32}$-in. cotton [2] [2], are entered for corresponding grades. For example, the average 1956–57 price for Good Middling $1\frac{1}{32}$-in. cotton is shown at $176/bale. If bales of this grade change in storage to Good Middling Spotted, the value is reduced to $153/bale; if they change to Good Middling Tinged, it is reduced to $129, and to $115 for Yellow Stained. The small changes involved in storage under favorable condition, and the large changes involved under adverse conditions, may be translated into relative dollar differences for the 1956–57 crop by reference to Figure 15.

[2] In 1956–57 11.7% of the crop was 1 in., 28% was $1\frac{1}{32}$ in., and 29.9% was $1\frac{1}{16}$ in.

Summary and Recommendations

In this study changes in color are reported for several sets of cotton from 1956 grade standards bales stored under 14 conditions of temperature and humidity. Temperatures varied from 0° F. to 100° F. The relative humidity was uncontrolled (and high at about 85%–90%) for all temperatures, and for three temperatures (50°, 70°, 100°) it also was kept at a relatively low humidity (about 50%). Color measurements are reported for samples before storage and periodically during storage up to a little over 1 year. The study will be continued for 3 years, but the picture regarding color change already has become so clear that results are reported for the first year.

Yellowing, or the deepening of the normal yellow color in cotton [8], is a matter of great concern in cotton storage. In spite of the darkening introduced into these particular test results by the unwanted and unusual introduction of *Penicillium* mold (through storage in chambers containing fruits and vegetables), from the results shown in the series of color diagrams, Figures 2 through 12, it seems clear that to hold changes in cotton color to a minimum in storage, refrigeration alone is not the answer. Storage under moderate temperatures (50°, perhaps even 60°) accompanied by controls that keep the relative humidity reasonably low (50% or less) should succeed in holding color change to a satisfactory minimum for at least 2 or 3 years. Where it is not feasible to control temperature, a control of humidity alone should succeed in reducing the degree of color change in storage that might otherwise take place within any given period.

It seems reasonable to suppose that there would be even less color change at humidities lower than 50%. However, if 8.5% is the accepted regain (the amount of moisture cotton will take up from a bone

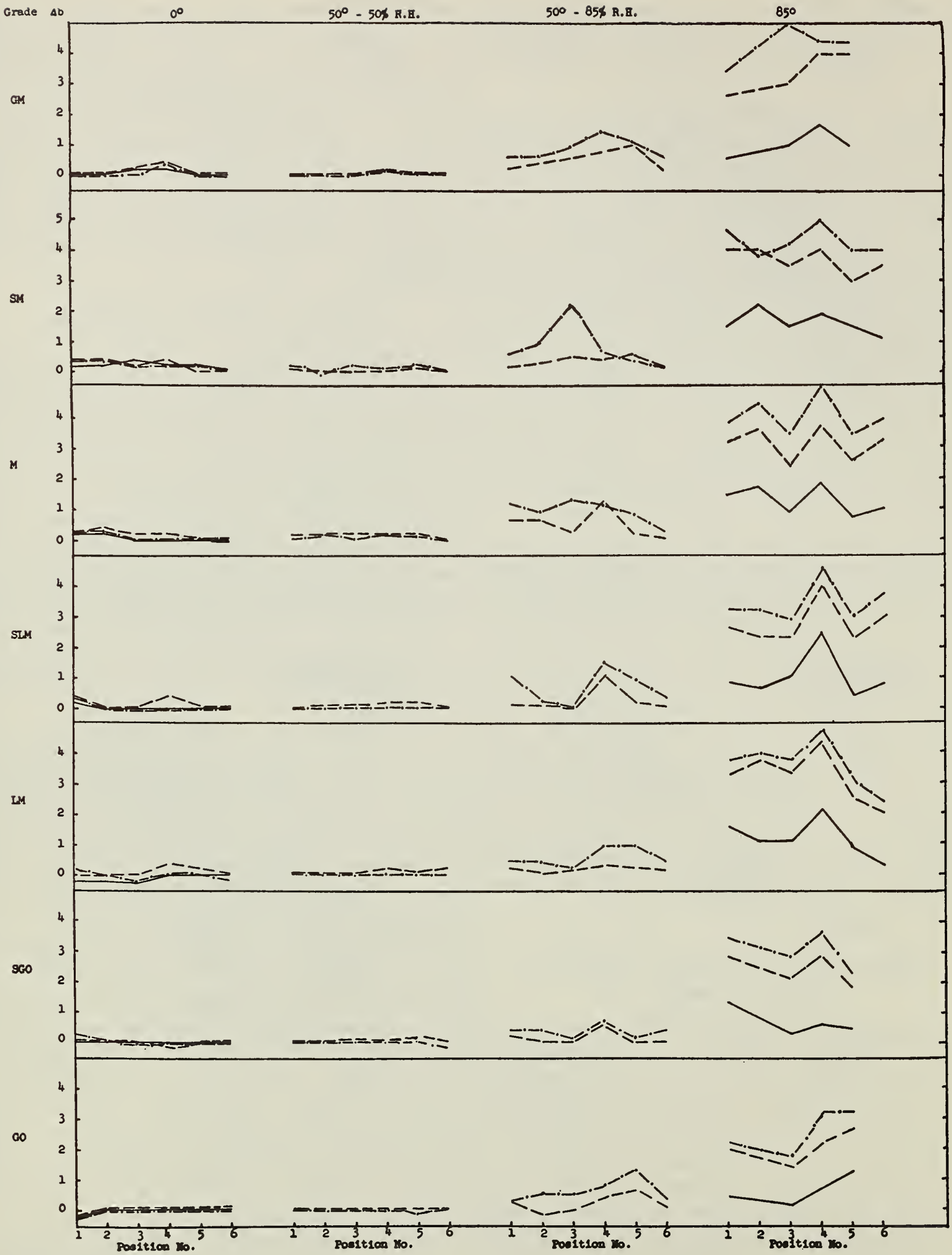
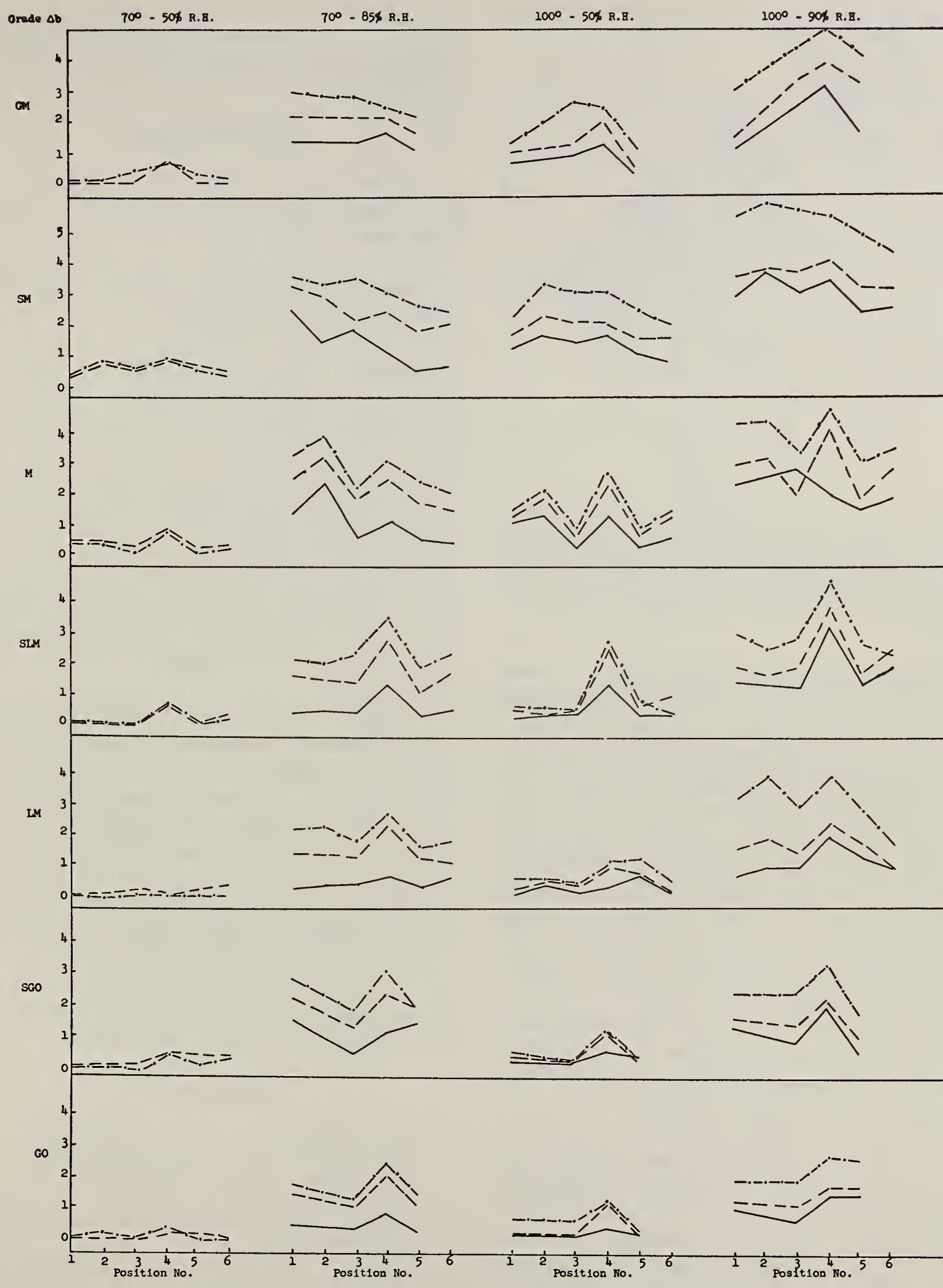


Fig. 14. Effect of storage on cottons from different areas. Cottons stored under several conditions of temperature and humidity; measurements in terms of differences in yellowness, Δb (measured on Cotton Colorimeter). Positions Nos. 1 and 2 are from the South Central area; No. 3, Southeast; No. 4, West; Nos. 5 and 6, Southwest. Code for storage:



—, 5 months; — —, 9 months; —·—, 13 months. A change of 2–3 units ($\triangle b$) is enough to cause a shift from one color class to another, as from White to Spotted; a change of 4 or 5 units is enough to shift the grade from White to Tinged.

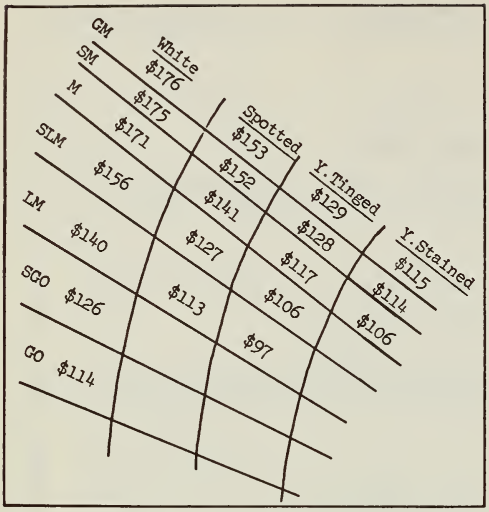


Fig. 15. Price per bale to nearest dollar, based on 1956–57 average spot quotations for 14 designated markets for 1 1/32-in. cottons, for White, Spotted, Yellow Tinged, and Yellow Stained grades shown (Good Middling through Good Ordinary).

dry condition) for cotton at the standard test conditions (70° F., 65% R.H.), then it seems undesirable to set storage specifications for relative humidity any lower than necessary, since the moisture in the cotton will be less at low humidities. Classing is done under conditions specified for many rooms at 73°/58%, and samples taken from cottons stored at 50% humidity will not be far from ready for normal classification in these rooms, while it might be necessary to condition samples taken from storage at much lower humidities. If it were *necessary* to specify storage conditions much lower in order to keep the cotton from changing, then it might be worth the extra trouble involved in conditioning samples and/or bales when they are taken from storage. But for the present, it seems satisfactory to specify 50% as the upper humidity limit for storage.

Therefore, on the basis of information provided by the test results reported, and until further work shows the advisability for further modifications, it is recommended that 50° F., 50% R.H. (with reasonably wide tolerances) be specified as the conditions to be maintained for storage of standards between conferences, and that dehumidification facilities be installed to keep the relative humidity at no more than 50% in space in which standards bales are stored after purchase. While these specifications are developed for U. S. Department of Agriculture use, the implications of this recommendation are important to all who hold cotton in storage for long periods.

Acknowledgments

Appreciation and thanks are expressed to Dr. H. C. Diehl, Director of the Refrigeration Research Foundation, through whom we located storage chambers of the sort that were necessary; to Dr. Harold T. Cook, Biological Sciences Research, Agricultural Marketing Service at Beltsville; and Dr. J. G. Woodroof of the Food Processing Division of the Georgia Experiment Station at Experiment, Georgia, for making space available in storage chambers used under their direction for other tests; to Mr. Q. W. Roop, Tobacco Division, Agricultural Marketing Service, who arranged for preliminary storage tests in cold storage space assigned to tobacco work; to Dr. Paul B. Marsh and Dr. Luis E. Gregory, Cotton and Other Fiber Crops Section, ARS, for making microbiological tests on selected samples from these tests; to members of Dr. Cook's staff at Beltsville and of the Cotton Division's staff in Atlanta who helped get our boxes of samples in and out of storage as required.

It might be noted that the storage chambers of AMS at Beltsville, together with those of the Georgia Experiment Station, provide the best facilities for a storage study of this sort that are anywhere available; we are therefore most grateful to Dr. Cook and Dr. Woodroof for the use of these chambers even though our results had to account for and discount the changes caused by storage in chambers contaminated by molds not usually found in cotton storage. We are sorry that uncontaminated chambers were not available for cotton storage, but since they were not we appreciate the cooperation that allowed us the use of those being used for other purposes.

Literature Cited

1. *The Classification of Cotton,* USDA Agri. Mktg. Serv. Misc. Pub. No. 310 (revised) 1956.
2. *Cotton Price Statistics* (*Season 1956–57*), USDA Agri. Mktg. Serv. **38**, 1–33 (1957).
3. Marsh, P. B. et al., TEXTILE RESEARCH JOURNAL **21**, 564–587 (1951).
4. Nickerson, D. and Milstead, L. D., *Studies of Stability of Color in Raw Cotton: A Preliminary Report,* USDA (1933).
5. Nickerson, D., *Effect of Exposure and Storage on*

Color and Other Factors of Quality in Raw Cotton, USDA (January 1951).
6. Nickerson, D., *Color Measurements of Cotton: Second Report on Application of Nickerson-Hunter Cotton Colorimeter, Including a Discussion of Recent Work on Standards for Grade,* USDA 1953).
7. Nickerson, D., *Color Measurement Data Relating to Grade Standards for Cotton and Cotton Linters,* USDA (1956).
8. Simon, S. A. and Harmon, C., TEXTILE RESEARCH JOURNAL **24**, 12–16 (1954).

Manuscript received January 31, 1958.

Reprinted from TEXTILE RESEARCH JOURNAL, Vol. XXVIII, No. 6, June, 1958
Printed in U. S. A.

Sugar, pH, and Strength Changes in Cotton During Storage

U. S. Department of Agriculture
Agricultural Marketing Service
Washington 25, D. C.
January 31, 1958

To The Editor

TEXTILE RESEARCH JOURNAL

Dear Sir:

On a selection of samples reported in a recent study [3], measurements [1] were made of sugar content (percentage of soluble reducing sugar) and acid-alkalinity (in pH units). Sugar content of cotton decreases as fibers mature; therefore, a high sugar content may indicate immaturity, as in Tinged cottons, in which cotton bolls may be opened prematurely by frost. (Or it may indicate contamination with honeydew.) As cottons remain in the field and become lower in grade, sugar content usually disappears. Its disappearance may be associated with an increase in pH that results from the action of micro-organisms. As reported by Marsh [2], the pH test offers promise as a rapid method for detecting growth of micro-organisms on cotton.

To study the sugar and pH change under storage in comparison to the color changes, measurements were made on samples stored at 0° and 85° F. at high humidity, and for samples held under two conditions of humidity at 50°, 70°, and 100°.

The distribution of sugar and pH seems to change only at those conditions in which there was considerable microbiological growth. Even at 90% humidity there was no significant sugar or pH change at 100° storage, although the change in color is even greater at this condition than it is at either 85°/high humidity or at 70°/85%.

Because it seemed possible that the very dark samples in this study which resulted from high *Penicillium* contamination might also be weaker in strength, tests for strength were made on a few of the cottons. But no strength loss was found,[2] even for samples that had shown the greatest change in sugar and pH. The strength of samples that were low in color after storage remained about the same whether they had yellowed only in the direction of normal aging or whether they had yellowed and had also darkened because of *Penicillium* mold. If the tests showed any difference in strength it was in the direction of an increase rather than a decrease.

Results for this study for sugar, pH, and strength tests are assembled in the accompanying Figure 1 for comparison. The data show clearly that there are greater changes in the high grades than in the low, and that the only real changes occurred under high humidities at temperatures 50°–85°.

A study of the relation of sugar and pH to color change, particularly for the paired samples at the same temperatures but different humidities, seems to show that only minor differences in sugar and pH

---

[1] According to methods reported in Cotton Testing Service, Agri. Mktg. Serv. Report No. 16 and in Regulations and Fees for Cotton Testing Service, Agri. Mktg. Serv. **38**: 1–33.

[2] Some types of micro-organisms do cause a change in strength [1].

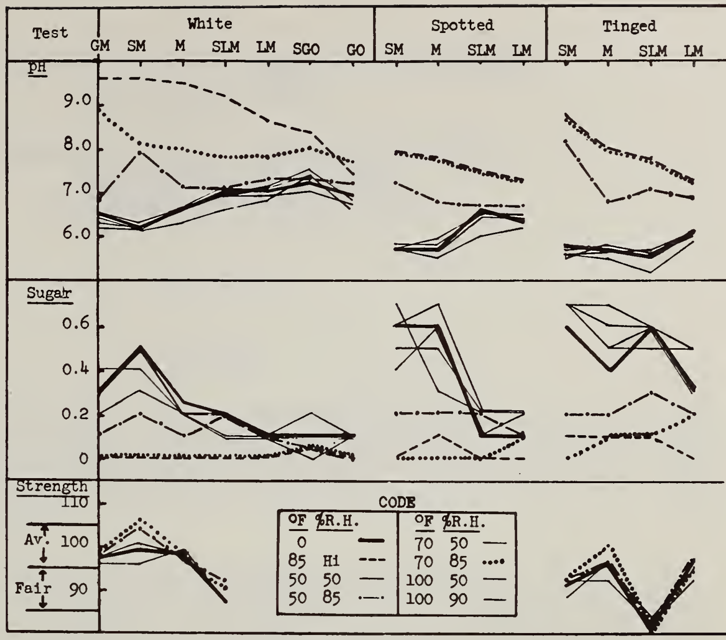


Fig. 1. Sugar and pH tests on cottons after 9 months storage at conditions ranging from 0° to 100° temperature and high (85%–90%) to low (50%) relative humidity, and strength tests (Pressley index) on a few White and Tinged grades that showed wide changes in color, sugar, and pH. The only real changes occurred under high humidities, and there the changes are greatest in the higher grades. No significant changes occur in strength; certainly there is no loss in strength.

occur even for large color changes when the color change is chiefly in the direction of increasing yellowness that is normal to cotton storage, but that there are large changes in both sugar and pH when there is microbiological action in the presence of high humidities. It therefore seems probable that while the change in these factors is closely related to microbiological activity (which sometimes results in a color change, sometimes not), it is not closely connected with the chemical changes involved in the normal yellowing of cotton with age.

Literature Cited

1. Marsh, P. B. et al., Textile Research Journal **19**, 466–474 (1949).
2. Marsh, P. B. et al., Textile Research Journal **21**, 564–587 (1951).
3. Nickerson, D. and Tomaszewski, J. J., Textile Research Journal **28**, 485–497 (1958).

Dorothy Nickerson
Josephine J. Tomaszewski

Cotton Division, AMS, U. S. Dept. of Agr., Washington, D. C.
For Administrative Use — September 1959

ROUGHNESS AS A FACTOR OF COTTON GRADE MEASURED BY SPINNING TESTS

By Franklin E. Newton, Cotton Technologist
Standardization Section
Standards and Testing Branch

PURPOSE

This report contains recent fiber and spinning test results on cottons designated as "smooth," "rough," and "gin-cut" by merchant classers. These words describe the degrees of preparation in cotton as determined by classers. Preparation in cotton, along with color and leaf, is one of the three primary factors of grade.

Preparation is defined in "The Classification of Cotton" 1/ as the degree of smoothness or roughness with which the lint is ginned, and the relative neppiness or nappiness of the ginned lint. This publication also comments on the effect of preparation on spinning utility as follows:

> "Various methods of harvesting, handling, and ginning cotton produce differences in roughness or smoothness of preparation that sometimes are very apparent. However, laboratory tests do not support the belief that these easily recognized differences in degree of preparation in the raw cotton will follow through to produce equally important differences in spinning results. As a general rule, smoothly ginned cotton results in less waste, and produces a slightly smoother and more uniform yarn than roughly ginned cotton. Except for cases in which the roughness is excessive enough to cause the cotton to be reduced in grade materially below that of cotton having normal ginning preparation, laboratory experience does not show significantly lower results for yarn tests."

This statement is based on research data reported by Bennett and Gerdes in 1936 2/ and on unpublished data within the Department. All of this previous research on the effects of preparation on the spinning utility of cotton dealt with the government classers' concept of preparation.

1/ U. S. Dept. Agr. Misc. Pub. 310. Revised June 1956.

2/ Bennett, Charles A. and Gerdes, Francis L. Effects of Gin-Saw Speed and Seed-Roll Density on Quality of Cotton Lint and Operation of Gin Stands. U. S. Dept. Agr. Tech. Bull. 503. February 1936.

Although standards for the grades of cotton show slight increase in roughness of preparation allowed for each grade from Good Middling to Good Ordinary, the differences are not easily distinguished. When a sample is reduced to Strict Low Middling from Middling on account of preparation, this does not mean that the sample has the preparation shown by the Strict Low Middling box. The roughness of a one-grade reduction is usually below the preparation shown by the Good Ordinary box. When a sample is reduced one or two grades because of poor preparation, the grade to which reduced, and the notation "Prep" is shown as part of the grade designation on official classing certificates. Gin-cut cotton is defined as cotton showing "damage in ginning, through cutting by the saws, to an extent that reduces the value of the cotton by more than two grades." 1/

Classification of cotton in the trade does not always strictly follow these rules and may vary somewhat from merchant to merchant and mill to mill. This report is based on merchants' interpretation of preparation and a comparison of the Department's class of the same samples.

PROCEDURE

Thirty-three spinning samples of cotton, table 1, were obtained that were selected by classers employed by the trade, 11 each designated as "smooth," "rough," and "gin-cut." The samples were reclassed independently by classers of the United States Department of Agriculture; comparisons are made in the section on results.

Small scale spinning tests, made at the Cotton Division's spinning laboratories according to previously developed standard procedures, 3/ provide the fiber and processing results reported for the 33 lots studied. The samples were processed into 22's and 50's carded yarns.

RESULTS

Only one out of 11 lots designated "rough" by merchant classers was reduced in preparation by the Department classers. None of the samples classed as "gin-cut" by the trade was reduced as much as three grades and only one by two grades.

According to Miscellaneous Publication No. 310, gin-cut cotton is cotton that shows damage in ginning, through cutting by the saws, to an extent that reduces the value of the cotton more than two grades. It is very evident from the comparison of government and merchant classification that the trade's conception of "gin-cut" is much more strict than that of government classers.

If the merchant's class is indexed on the basis of "smooth" being assigned no reduction, "rough" a one-grade reduction, and "gin-cut" a two-grade reduction, the average grade index for all lots turns out to

---

3/ U. S. Dept. Agr., Agricultural Marketing Service, Cotton Division, A.M.S. No. 16, Cotton Testing Service, February 1955.

be the same for both classifications, as shown in table 1. The main difference between the two classifications seems to be in the relative assessment of grade factors in arriving at a final classification. Samples low enough to be classed officially as gin-cut would have to be much rougher in preparation than the lots in the study listed by the trade as "gin-cut."

The grade index, as determined on the basis of the Department class (figure 1) for the cotton classed "Middling" by the trade decreased from 99 (smooth) to 88 (gin-cut) and for those classed as "Strict Low Middling" it decreased from 90 to 77. In other words, the difference between the concept of "smooth" and "gin-cut" by the trade for these samples was about 1-1/2 grades when based on official classification of the same samples. It was intended that the staple length should be the same. As shown on figure 1, staple for the "Middling" samples varied within a thirty-second (32.7 thirty-second for "smooth," 32.3 for "rough," and 33.3 for "gin-cut"), and for the "Strict Low Middlings" just slightly under 33 for all three categories.

The nonlint content (figure 2) increased from 2.3 percent (smooth) to 5.5 percent (gin-cut) for "Middlings" and 3.8 percent (smooth) to 5.8 percent (gin-cut) for "Strict Low Middlings." Manufacturing waste (figure 2) increased from 6.7 percent (smooth) to 9.5 percent (gin-cut) for "Middling," and increased slightly for "Strict Low Middling" (8.2 percent, to 9.0 percent). Thus nonlint content and manufacturing waste (figure 2) increased for the "gin-cut" samples over the other two categories.

The appearance of yarns (figure 3) made from these cottons was not consistent with the preparation as designated by the trade classification. Yarn strength, indicated by the breakfactor (figure 3), of the "gin-cut" cottons was higher, but this seems mainly due to higher fiber strength for several lots classed "gin-cut." Thus results showed no consistent relationship between either yarn appearance, or yarn strength, and the degree of preparation.

CONCLUSIONS

These fiber and spinning test results, on cottons selected by the trade to represent their concept of "smooth," "rough," and "gin-cut," tend to confirm earlier findings for cottons similarly designated by the Department, namely, that "easily recognized differences in degrees of preparation in the raw cotton will not follow through to produce equally important differences in spinning results," although "smoothly ginned cotton generally results in less waste and produces slightly smoother yarn than roughly ginned cotton." Even when reduced by Department classers one grade due to preparation, some of these lots were not significantly different in waste or yarn appearance from more smoothly ginned samples.

It was observed in the course of this study that classers generally seemed to give substantial weight to "smoothness" or "roughness" as a factor of preparation in cotton. When samples were nappy, this nappiness

was clearly apparent, and contributed to the classer's determination of roughness. But the definition of preparation also includes neppiness, and this is a factor not so easily distinguished although it is known to affect yarn appearance.

While the Department will continue the study of neppiness and nappiness as factors of preparation in raw cotton and their effect on the spinning utility of cotton, it is concluded, on the basis of this and previous studies, that in standardization and classing of preparation, less weight need be given by the classer to roughness or smoothness of appearance and more consideration should be given to neppiness.

Table 1.-Merchant and Government classification of 33 spinning lots, with grade index approximations

Lot No.	Cotton Grade Classification 1/			
	Merchant 2/	Index	Government	Index
1	M smooth	100	M	100
2	M "	"	M	100
3	M "	"	M	100
4	M "	"	M	100
5	M "	"	M	100
6	M "	"	M Lt Sp	96
Average		100		99
7	M rough	94 3/	M Lt Sp	96
8	M "	"	M Lt Sp	96
9	M "	"	SLM Lt Sp/M Lt Sp	88
Average		94		93
10	M gin-cut	85 3/	M Lt Sp	96
11	M " "	"	M Sp	93
12	M " "	"	SLM Lt Sp/M Lt Sp	88
13	M " "	"	" "	88
14	M " "	"	" "	88
15	M " "	"	LM Lt Sp/SLM Lt Sp	80
16	M " "	"	" "	80
Average		85		88
17	SLM smooth	94	SLM	94
18	SLM "	"	SLM	94
19	SLM "	"	SLM	94
20	SLM "	"	LM	85
21	SLM "	"	LM	85
Average		94		90
22	SLM rough	85 3/	M Lt Gr	94
23	SLM "	"	M Lt Gr	94
24	SLM "	"	SLM Lt Sp	88
25	SLM "	"	SLM Lt Sp	88
26	SLM "	"	LM Lt Sp/SLM Lt Sp	80
27	SLM "	"	" "	80
28	SLM "	"	" "	80
29	SLM "	"	" "	80
Average		85		86
30	SLM gin-cut	76 3/	SLM Lt Sp/M Lt Sp	88
31	SLM " "	"	LM Lt Sp/SLM Lt Sp	80
32	SLM " "	"	" "	80
33	SLM " "	"	BG/SLM Lt Sp	60
Average		76		77
Grand Ave.		89		89

1/ Lots reduced were due to rough preparation.
2/ Merchant classification on individual bales is not a composite grade.
3/ The merchant's class was given in three steps. To assign indexes the "rough prep" samples arbitrarily were given a one-grade reduction and the "gin-cut" a two-grade reduction. (Officially, a gin-cut sample requires a three-grade reduction.)

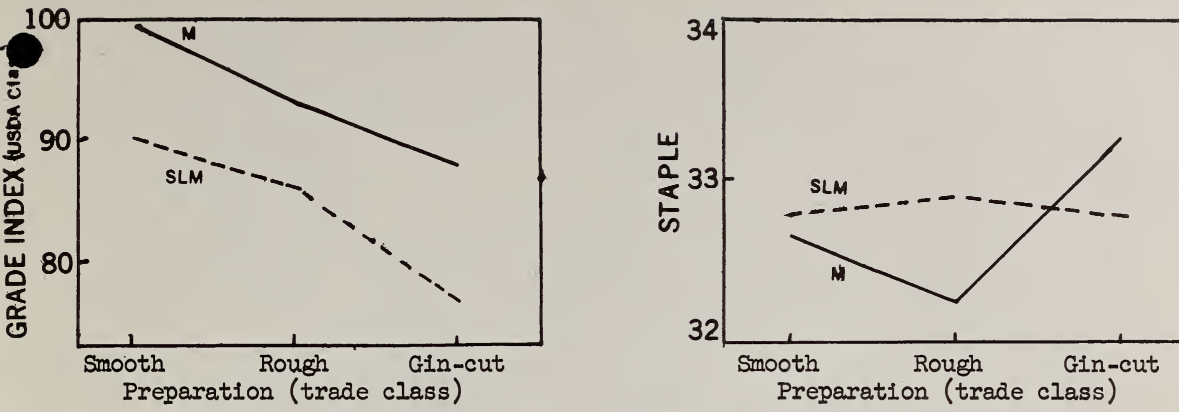


Figure 1.--Grade Index and Staple (as classed by government classers) for "Middling" and "Strict Low Middling" lots for three degrees of preparation selected and classed by trade classers to represent smooth, rough, and gin-cut cottons.

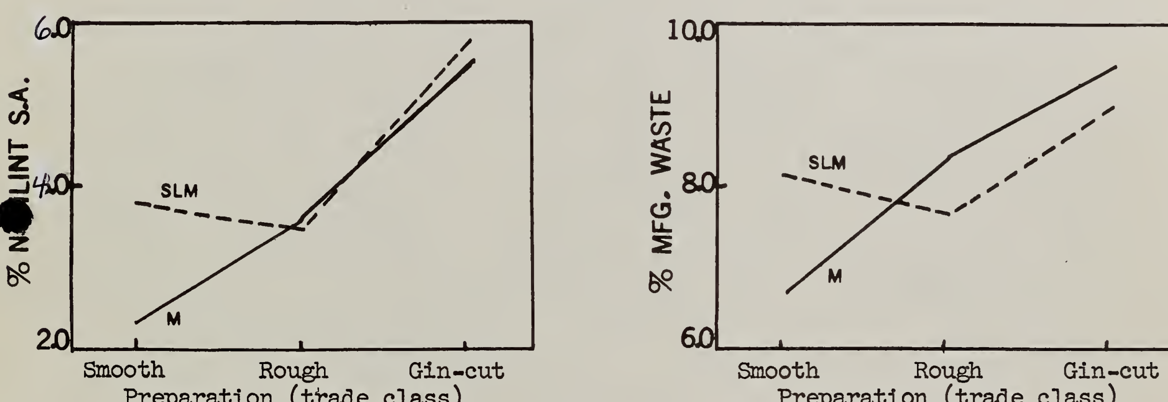


Figure 2.--Shirley Analyzer nonlint and manufacturing waste for three degrees of preparation, smooth, rough, and gin-cut.

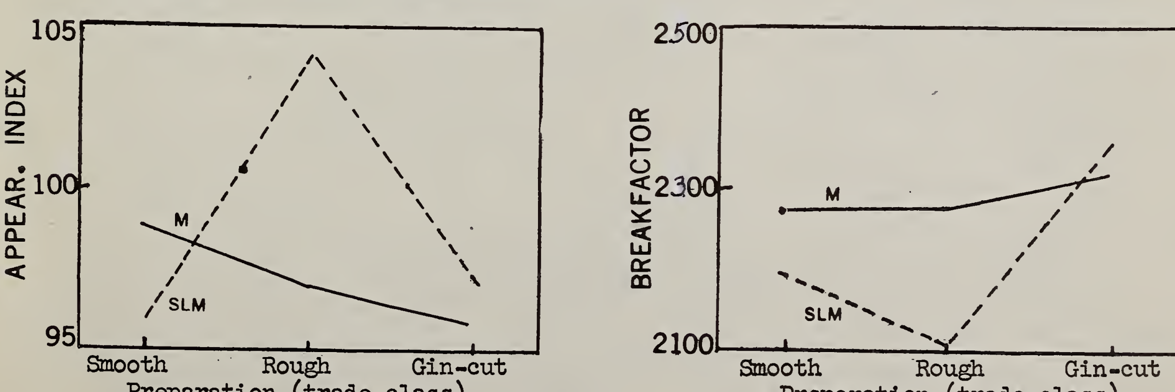


Figure 3.--Average appearance index and breakfactor for three degrees of preparation, smooth, rough, and gin-cut.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

COTTON COLORIMETER

An Aid in Extending Knowledge of Cotton Quality

A report by Dorothy Nickerson,* Cotton Division, at the
Open House of the American Cotton Manufacturers Institute, Inc.,
Clemson, S. C. — May 4, 1960

In connection with work on grade standards, the color of raw cotton has been measured in the Cotton Division of the U. S. Department of Agriculture for over 30 years, first (1929-1950)[1] on a disk colorimeter (1, 2), a visual instrument especially designed for measuring the color of raw cotton, next on the Nickerson-Hunter Cotton Colorimeter[2] which was first produced in 1950 by the Gardner Laboratory as a rapid, automatically self-standardizing photoelectric instrument employing barrier layer cells as the sensing unit (3), and produced since 1959 by Spinlab in an instrument[3,4] intended for the same purpose but employing phototubes (1P-39) as the sensing unit, and based on a fundamentally new design by Hunter that incorporates features intended to avoid difficulties found with earlier instruments, improve its accuracy and precision, and simplify the method of calibration and maintenance.

The cotton colorimeter, whether old or new, basically is a color-difference meter, designed to make rapid measurements over an area larger than is usual with most colorimeters, and to operate over the range of cotton colors on scales that are widely expanded in the region of these colors. It measures (4, 5, 6) the relative lightness or darkness of color in terms of percent reflectance (R_d), and the degree of yellowness in terms of Hunter's scale of "+b." The heart of the instrument—the feature that distinguishes it as a cotton colorimeter—is the grade diagram used with it.[5] This diagram was developed by the U. S. Department of Agriculture, based on measurements of the Universal Standards for grade of American upland cotton, tied down to fundamental colorimetric measurements used in calibrating the scales of a master instrument in the Washington laboratories of the Cotton Division. The color range of the diagram can be illustrated by a color chart[6] superimposed over it. Each instrument of any given model or type is provided with a grade diagram and with a set of colorimetric standards[7] (7) by which it may be kept in calibration with a master instrument. Cottons should measure the same grade color, and the same R_d and b values, whether measured on old or new models of the instrument.

---

* Head, Standardization Section, Standards and Testing Branch.

1 The superscript numbers refer to lantern slide illustrations; numbers underlined in parentheses, refer to List of References.

While the colorimeter's first use is to maintain standards on a constant level, it is equally useful in the classing room to help the classer keep on a constant level.[8] When cotton samples are similar to the grade standards in combinations of color, leaf, and preparation the colorimeter measurement indicates the grade; when samples vary from the standards in combinations of these grade factors, the classer will find the colorimeter an aid in assessing the grade of the combination, for he can visually judge the amount of leaf and degree of preparation, and from the instrument he can obtain a measure of the color level of the combination, something that it is hard for the eye to judge correctly when the usual clues are lacking, clues such as the amount of leaf expected to accompany the color of any given grade. The instrument is better than the eye in measuring the absolute level of color[9,10,11] but it can report only the integrated color of whatever sample is placed on its viewing window. The eye, on the other hand, can differentiate between fiber and trash, and can distinguish extremely small differences in color. In fact the tolerance requirements for precision which must be met in order that colorimetric instruments may equal the very remarkable ability of the human eye to distinguish small differences, are fantastically small when compared to the precision of most of the fiber testing instruments in our cotton laboratories today.

The speed of the instrument should be mentioned. Measurements of one thousand or more samples a day by one operator handling and recording the data is not at all unusual.

A color measurement consists of the R_d and b combination that pinpoints one color in relation to another. The factors have no real color meaning when considered separately except when it is assumed that the missing factor is being held constant; for example, an R_d measurement of 70 may refer to LM, SLM, SLM Sp., M Sp., SM Sp., SM Tg., or even to GM Tg., depending upon the +b measurement associated with it. Measurements of reflectance for cottons may vary from 82% for a very white GM to 50% for a low GO, while the b factor may vary from 4 or 5 for some of the lower grade cottons to as much as 16 for a high grade Yellow Stained cotton. Within this range of color, when the instrument is held in calibration, it is possible to hold readings on uniform color surfaces of paper, enamel, and tile standards very precisely. Repeat readings on cotton samples, as they are prepared for use in the cotton grade standards, show very slight variations because of the non-uniformity of their surface and the improbability of replacing exactly the same area on the instrument window each time it is remeasured. Different samples from the same bale show more variation, while samples of the same grade but from different bales cover a considerable range in color, the range for lower grades being greater than for high grades. The relative degree of color variation expected for these different criteria are listed in table 1 and may be demonstrated on a color diagram.[12]

As these data indicate, the instrument itself is capable of very precise measurements, but the repeatability on any cotton sample depends upon the sample itself and the particular face selected for

Table 1.--Repeatability of measurements on the Nickerson-Hunter Cotton Colorimeter (Spinlab Model 191) for samples in different conditions as demonstrated by relative size of standard deviations around the means of R_d and b readings in the color range of the several grades

Color range of grades	Papers and enamels 1/ % R_d	Papers and enamels 1/ +b	Same samples, 2/ repeat readings % R_d	Same samples, 2/ repeat readings +b	Different samples, 3/ same bales % R_d	Different samples, 3/ same bales +b	Different bales 4/ % R_d	Different bales 4/ +b
	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.
GM	.08	.04	.12	.06	.46	.09		
SM			.10	.06	.42	.15	1.5	.46
M			.13	.05	.30	.12	1.5	.42
SLM	.09	.05	.08	.06	1.0	.18	1.7	.52
LM	.00	.05	.11	.07	1.3	.19	2.2	.50
SGO			.08	.07	1.1	.16		
GO	.02	.06	.13	.07	1.2	.16		
	.07	.07						
	.00	.05						
SM Sp.	.07	.00	.09	.06	.36	.14	1.7	.34
M Sp.	.05	.00	.09	.07	.61	.26	1.7	.66
SLM Sp.			.14	.07	.72	.26	1.5	.65
LM Sp.	.09	.02	.08	.06	.78	.20	2.4	.28
SM Tg.	.08	.06	.09	.07	.81	.40		
M Tg.			.11	.06	.62	.28		
SLM Tg.			.11	.08	1.6	.64		
LM Tg.	.09	.07			.78	.27		
	.03	.06						

1/ Twenty-five independent measurements on each of several papers and enamel plaques used to test colorimetric accuracy of instrument.

2/ Twenty-five independent readings made over a period of several weeks on six cotton samples of each grade.

3/ One measurement on each of 12 cotton samples from the same bales.

4/ The samples in this series were taken at random from the 1959 Annual Quality Study. Up to 30 different bales are represented in each grade. (The spotted bales were Light Spotted.)

measurement. If the low side of a sample is measured, the color will read lower than for the high side. If a heavy wrinkle is formed in the sample as it is measured through the viewing window, this will show up as a shadow and the color will read lower than for a more representative sample. If the face measured has either too much, or too little, leaf to represent the sample adequately, the color will measure correspondingly too dark or too light. Just as a classer must have an adequate sample, so must the instrument.

At this point it might be brought to your attention that the instrument may be adapted for use with other products than American upland cottons. Grade diagrams have, in fact, been developed for American Egyptian cottons,[13] for cotton linters,[14] and an instrument now in our Tabacco Section is being adapted for use with tobacco products.

You have on exhibit at this meeting the cotton colorimeter made by Spinlab (Model 191). It incorporates several features we find very useful, and while a few of these will be discussed in this report we shall not attempt a detailed discussion of the instrument itself, either this model or the earlier ones, for each is illustrated in detail in the instruction manual that accompanies it. We intend, instead, to concentrate attention on the various uses that may be made of color measurements on cotton.

First we might demonstrate an adaptation of the original cotton grade diagram developed several years ago and now proposed either for supplementary or replacement use on the instrument. In our own use of the colorimeter, R_d and b scale readings are seldom recorded; instead, either the equivalent grade is recorded, or the sample measurement is indicated directly on a diagram of the grade standards. Only when color results are to be tabulated, as for statistical studies, do we record R_d and b. Yet because it would be useful to have a closer color identification than that of a full grade, a diagram[15] has been developed in which each grade is divided into a high and low side for reflectance, and into three zones for yellowness—a central zone, one to the white side and one to the yellow side of the grade. To make it easy for the cotton man to identify color in relation to the grade standards, a code is provided that consists of three numbers: the first relates to grade (3, Good Middling; 4, Strict Middling, etc.); the second number relates to placement in the upper or lower half of the grade, for example, 30 for the top half of GM, 35 for the lower half of Good Middling, 40 for the top of SM, etc.; the third number, beginning with 1 to represent the whitest side of the grade, increases in number through the White and Spotted grades to 9 for the deepest color in the Tinged grades. Color deeper than that in the Yellow Tinged grades, is designated by zero in this third code number. The number 401 thus designates SM on the high side of the grade, and very white—a color typical of SM cottons from California. The code number 403, on the other hand, designates SM on the high side of the grade, but more yellow in color, typical of SM from the Texas and Oklahoma area. The number 457 would indicate SM on the low side, with 7 degrees of yellow color, enough yellow to put it into a Tinged grade.

Such a code for recording equivalent cotton color will, we believe, provide the classer with a tool that relates to his knowledge of grade standards; it allows him to distinguish colors within grades, and adapts itself easily to the needs of computer techniques.

You may wish to have a brief look at the new instrument, and how it works. In this latest model,[16] phototubes have been used in the instrument. These provide more electrical response than photocells, therefore the instrument requires less amplification than earlier instruments, and switching troubles are avoided. A special circuit includes use of a unique lamp regulator and a constant voltage transformer. An electrostatic chopper-stabilized amplifier feeds the output of the phototubes to the system of servo-mechanisms which operate the indicator bars. The intersection of these crossbars indicates the color of the sample in terms of percent R_d and +b. The scales of R_d and b on this instrument have been made linear. They are adjusted so that on the diagram 1-inch represents 5% R_d, or two units of +b. The calibrating controls are mounted on the front panel, easily accessible. Use of a new balancing circuit allows considerable ease in calibration by freeing the b calibration from the R_d position on the scale.

The color head[17] of the instrument is equipped with two reflector lamps adjusted at 45° incidence on the sample. Light reflected from the sample is picked up by a diffusing screen and directed through a light pipe of clear plastic to phototubes located beneath it in a thermostatically regulated aluminum block. One of the important new features of the instrument is this thermostatic regulation of the phototubes, for it aids greatly in providing high precision of readings. Three filters are cemented to the bottom of the light pipe, one amber (Y) and two blue (Z) filters. The R_d measurement is determined by one phototube through the Y filter, while b is determined by a combination of the Y and Z phototubes. The phototube-filter combination provides colorimetric measurements in terms of Hunter's R_d and b that is based upon as accurate a conversion as is available today to internationally accepted C.I.E. standards for colorimetry.

And now, regardless of what model colorimeter may be used, there are many things that may be done with the resulting color information, among them the following:

1. To maintain uniformity and a constant level of color in production of cotton grade standards.
2. To measure relationships of color, leaf, and preparation factors in grade standards versus those in currently marketed cottons.
3. To aid the classer in maintaining a constant level of grade classification.
4. To establish facts concerning color change and its causes.
    a. Change in color by exposure in the field before harvesting.
    b. Change in color during storage after ginning.
5. To establish facts concerning effects associated with color in cotton processing or end use.

The earliest use of the colorimeter was to measure the standards themselves, then to measure all replacement bales to insure that color was maintained as near as possible to that in current standards boxes. Grade boxes of those days included representations of Middling Fair and three Blue Tinged grades, and there were descriptive standards for Extra White cotton—a designation more concerned with distinguishing between the irrigated and rain-grown cottons than with color itself. (The fact that many high grade Mississippi Delta cottons were quite as "Extra White" in color as cottons from irrigated regions, yet usually were graded white, while cottons from irrigated districts usually were graded Extra White, provided an early and important lesson to those of us working in the laboratory on cotton color; it was to study what the classer says in relation to what he does.) By studying results separately for areas or growths, color facts began to be sorted from misconceptions, and as the laboratory was able to put the resulting picture into diagrams that fit the classers' experience, the picture began to become more clear, and the classers were able gradually to eliminate inconsistencies and overlapping of grade factors in the standards.

The next slide[18] illustrates one of the earliest of our grade standards diagrams. It comes from a 1933 publication (8). Measurements in those days were plotted on scales closely related, although not identical, to the R_d and b scales used in present day instruments; the similarity to diagrams of today can be seen.

(While we have this slide on the screen, another application of color measurements may be noted by following the numbers 1 to 27. They illustrate the change in samples of cotton bolls that opened on the same day, but were picked week by week from the 1st to the 27th week, then measured for color. The color path taken by these samples clearly shows that exposure to weather results in progressively lowering the color and grade of cotton; the color gradually changed from SM in the first weeks to below GO at the end of the season. The extent and speed of color change depends upon weather conditions, in years of bad storms the color may go far Below Grade.)

The grade diagram of 1950 for the electronic cotton colorimeter included grades for Extra White,[19] and as the next slide illustrates, samples in several of the 1950 grades still showed some unintentional overlapping. This diagram fitted grade standards in effect, standards which the Department realized no longer represented the crop. They knew it in three ways: 1, because classers found new crop cottons far off the standards in color; 2, as a result of color measurements which showed current crops to be whiter than the standards; and 3, by the increasing difficulty their classers found in obtaining bales to put into standards—old crop cottons had to be searched out for use in the standards, searched for in the warehouse of shippers and mills. There was excellent cooperation in this search, but little cooperation in the suggestion that the standards be changed to bring them back to fit the crop.

Evidence from surveys based on crops following the 1950 conference was so overwhelming in showing the standards considerably more yellow than the crop,[20] that in 1952 the grade standards were changed to bring the color back to fit that of the crop. There was a great difference of opinion, many could or would not believe that it was the color of the standards that had changed, not the color of the crop. But color data for surveys, obtained on a colorimeter operated as easily by a classer as by a laboratory technician, and so rapidly that a very adequate sampling of the crop could be included, could be believed more easily than results from previous tests. A change finally was made in standards, although not without objection on the part of some who continued to insist that no change was necessary.

With the 1952 change, which became effective in 1953, a new grade diagram was necessary. (The relationship of the old and new is illustrated.)[21] The adjusted diagram is the one we use today; cottons are readily found in each new crop within the color range represented by this diagram. Note that no change in grade levels was made in these diagrams (except to eliminate the artificially smoothed faces of standards in GM and SM); the change consisted of a shift from the yellowed color of aged standards toward the whiter color of new crop cottons. Since 1952, cottons for grade standards are bought to fit the new diagram, according to specified positions for several areas.[21A]

But while current grade surveys show no color change in recent crops, they do show a very considerable change in the amount and kind of leaf associated with a given color in today's grades. The colorimeter, combined with Shirley Analyzer or trashmeter measurements, can help us to understand this change. For example, trash levels in bales bought for use in grade standards for a number of years, 1936-60[22] show that the amount of trash in cottons purchased for use in the standards has gradually been decreasing until, in the 1958 crop there was at least a full grade less trash, as measured by Shirley Analyzer (even in bales searched out for use in the standards) than there was in earlier standards. By contrasting the curve[23] for nonlint content for the 1958 crop against the curve of standards adopted and used since 1953, it may be seen that there is a one grade difference for grades SLM and below, and more than a grade difference for Middling and above. It should be noted that the nonlint content by Shirley Analyzer includes dust and motes, not just the leaf which the classer can see on the surface.

You may ask what color has to do with this. Almost everyone today is concerned with discussions of overcleaning and overdrying that may be the cause of cleaner grades. The opinion seems widely held that the only measure we have of this relates to an excess of short fibers. But if you will examine the color of such bales before and after cleaning on the Shirley Analyzer, it is clear that in early years there was a regular pattern of color improvement before and after cleaning, that amounted to a difference on the color diagram of at least one grade.[24] A series of diagrams contained in a study

reported to the 1959 Universal Grade Standards Conference (9) shows typical color changes before and after cleaning on the Shirley Analyzer for a great many samples measured from all cotton areas of the United States in crops of 1951-52-53 and 1958. The 1951-53 crops [25] show color improvement on removal of dust and trash by the Shirley Analyzer about like that obtained in previous studies. But samples studied from the 1958 crop [26] show practically no color improvement in the higher grades, and far less improvement in lower grades than for earlier years. In other words, an examination of the color of lint before and after removal of trash, is a very good way of judging whether a bale already has been through extra cleaning processes. The two slides that illustrate this show results that are typical for all areas studied. Such information does not tell anything about damage, but it does indicate that the color of the sample with very little trash is lower than it would have been for a sample of the same grade in which both color and trash were equal to the grade.

Another use for the colorimeter concerns studies of blending. Bright color, with excess leaf, or Light Spotted cottons in which the color will blend to give a suitable overall color, can be located by use of color measurements, particularly by measurements of cottons before and after trash removal. Blends of clean fibers may also be studied,[27,28] and they clearly indicate that lower grade colors carry greater weight in affecting the color of a blend than higher grade colors. In fact, in connection with the extra cleaning that cottons now are getting at the gin, there already has been a blending that spreads out, or blends, the color of spots, so that they are more detectable today by a colorimeter in the degree of yellowness in an overall background color, than as the definite spots that were clearly detectable in cottons of earlier years.

Although our most important use of the colorimeter in the Cotton Division, is as a tool in preparing the grade standards (measurements are made of every sample that goes into the standards) studies of color change in storage have also yielded important and practical results. From very early studies (10) it became evident that cotton changes in color during storage, and that this change is greater in a hot, humid climate than in a cool, dry climate.

Measurements of standards returned after use show that they deteriorate far more in color during use than most people realize. It is only necessary to expose boxes of the high grades for a few hours to the dust and dirt of the average classing room to find that they measure lower in color than when new. This dust layer affects all grades; many returned grades measure as much as one, and even two grades lower in color than when new. In fact, it is possible to judge by the color measurement how much use a grade box has received. To serve a useful purpose, standards must be used, but if they change rapidly in use, as well as in storage, then to keep them useful their validity period needs restriction. Beginning in 1956 grade standards have been valid for one year only.

With standards boxes valid for only one year, and international grade standards conferences held every three years, it became important to establish specifications for conditions under which standards could be stored to show a minimum color change. A special study was therefore undertaken in 1956 that included storage of full sets of standards under a wide range of controlled conditions, from 0° F. to 100° F., at 50% relative humidity and at humidities about 85-90%. The test was to run for three years, but after one year the results were so conclusive that an interim report was published (11) recommending 50° F., 50% R.H. as a practical set of conditions for inhibiting change during storage.

The results of this test,[29,30,31] published for extreme and recommended conditions (12), show little change even in three years for cottons held at 0°, or at 50° F., 50% R.H., but they show increasingly large changes for cottons held at higher temperatures and humidities. At 100° F., and humidity at 85%, GM and SM cottons changed to GM Tinged color within one year, and to deep Tinged and Stained grades in three years, a change that could amount to as much as sixty dollars per bale for 1-1/32" cottons. Samples of SM cottons stored in this test have been brought along to demonstrate to you the dramatic extent of color change that may result from storage.

To establish facts concerning effects associated with color in cotton processing or end use, studies relating to fiber, spinning, and finishing tests on cottons before and after accelerated change in storage are now nearing completion in our laboratories. Conditions of storage include those at 100° F., 85% R.H. for one year, and for two years' storage at 50° F., 50% R.H. and at 100° F., 50% R.H. Identical cottons have been stored under each condition. Results of these tests should provide definitive information on quality changes in cottons that may be associated with color, for these cottons initially were the same for all factors. Information to date indicates that associated with the color change there seems to be a lowering in a number of factors.

Studies relating color to fiber, spinning, and finishing test results for various grades of White, Spotted, and Tinged cottons are in process. We have been able to measure color for some time, now we are studying the effects associated with color, to discover the extent to which discounts for colored cottons may or may not be justified.

We know that color is highly associated with grade, for it is one of the important grade factors. It is also associated with the amount of manufacturing waste, and this seems to be true whether or not the cotton has had extra cleaning before reaching the mill. A low grade white, or a spotted, or tinged cotton has a higher percentage of manufacturing waste than the surface leaf indicates. In other words, a cotton with Middling leaf and either SGO color, Middling Spotted color, or Middling Tinged color, will have more processing waste than a cotton with Middling leaf and Middling color.

It is to be expected that color of raw stock, particularly the color of the cleaned lint (which may be measured in terms of the color of grey yarn) is associated with its ability to bleach and dye satisfactorily. To provide a method of measuring this finishing potential the Cotton Division expanded its tests in 1955 to include standardized color tests for bleached and dyed yarns. A special adaptation of the Color-Difference Meter allows color to be measured directly on yarn skeins. Measurements are made in terms of R_d and b coordinates as they are on the Cotton Colorimeter, bleached yarn colors in terms of R_d and +b, blue-dyed yarns in terms of R_d and -b. An index, based on these measures, and quite similar to the index developed for reporting cotton grades, has been developed (13), the scale being pegged so that 100 represents Middling and 70 represents Good Ordinary. On the basis of studies of bales that cover the range of the grade standards, correlation studies [32] show that the classer can explain 76% of the variation in color of the dyed cottons in terms of grade and staple, the laboratory can explain about the same amount. Yet it can be explained quite as well in terms of color measurements alone. A diagram with color samples covering the range of colors represented by this blue-dyed index, is illustrated.[33]

To illustrate the color differences throughout the grade range in more concrete form, we have brought along for your inspection a mounted set of yarn skeins covering the range of all grades for which we have standards, first in grey yarns, and second, in dyed yarns. The differences in grey yarns that follow through to the bleached and dyed yarns are apparent in this visual demonstration.

In this report it has been possible to discuss only the highlights regarding use of color measurements in extending our knowledge of cotton quality. We believe, however, that color studies, particularly of actual fiber color (that is, the cleaned lint) warrants far more attention than usually is paid to it by all except the classer, whose grade increasingly depends upon his estimate of color.

The appendix attached to this report contains a description of several of the most important color specification systems in use today, and discusses their interrelations. This information is included for those who wish to have background information concerning the meaning and derivation of color scales used today in various color measuring devices.

List of References

(1) Nickerson, D. A colorimeter for use with disk mixture. J. Opt. Soc. Amer. 21:640-642 (1931).

(2) Nickerson, D. Color measurement and its application to the grading of agricultural products: A handbook on the method of disk colorimetry. U. S. Dept. Agr. Misc. Pub. 580, 67 pp. (1946, reprinted 1958).

(3) Nickerson, D., Hunter, R. S., and Powell, M. G. New automatic colorimeter for cotton. J. Opt. Soc. Amer. 40:446-449 (1950).

(4) Judd, D. B. Color in business, science, and industry. 401 pp. Wiley (1952).

(5) Hunter, R. S. Photoelectric tristimulus colorimetry with three filters. J. Opt. Soc. Amer. 32:509-538 (1942) U. S. Natl. Bur. Standards Circular (C429), 46 pp. (1942).

(6) Hunter, R. S. A photoelectric color difference meter. J. Opt. Soc. Amer. 48:985-995 (1958). (Reprints available from Hunter Associates Laboratory, McLean, Va.)

(7) U. S. Department of Agriculture. Cotton Testing Service. (Test Item No. 23.2.) AMS No. 16 (1955)

(8) Nickerson, D. and Milstead, L. D. Studies of stability of color in raw cotton. A Prelim. Report. U. S. Dept. Agr. (Mimeo.) 22 pp. (1933).

(9) Nickerson, D., Tomaszewski, J. J., and Newton, F. E. Cotton Grade Studies, Trash and Color. No. 3 of 4 reports prepared for 1959 Universal Grade Standards Conference, U. S. Dept. Agr. (Cotton, AMS, 1959).

(10) Nickerson, D. Effect of exposure and storage on color and other factors of quality in raw cotton. U. S. Dept. Agr. (PMA 318, 1951).

(11) Nickerson, D. and Tomaszewski, J. J. Color change in raw cotton related to conditions of storage. Text. Res. J. 28, 6 (1958).

(12) Nickerson, D. and Tomaszewski, J. J. Color change in storage. No. 4 of 4 reports prepared for 1959 Universal Grade Standards Conference, U. S. Dept. Agr. (Cotton, AMS, 1959).

(13) Nickerson, D. and Newton, F. E. Grade and Color Indexes developed for evaluating results of USDA cotton finishing tests. U. S. Dept. Agr. AMS-245 (1958).

APPENDIX

Munsell Specification. The Munsell method of color notation was developed in the United States in the early part of this century. It may be used directly by comparison to samples on color charts or it may be used indirectly by converting C.I.E. 1/ data into Munsell terms. In the Munsell notation, color is expressed in units of visual difference of the three psychological attributes: Hue, lightness, and saturation. By this method results of color measurement are expressed in terms of color order rather than color mixture, and allow an interpretation of results in terms of the visual qualities known in the Munsell system as hue, value, and chroma.

Hue is that attribute of a color perception that determines whether it is red, yellow, green, blue, purple, or the like. Value is the expression of reflectance of an object color on a scale giving approximately uniform perceptual steps under usual conditions of observation. Chroma is the expression of the degree of departure of an object color from the nearest achromatic color (gray); under ordinary observing conditions Munsell chroma of a specimen correlates well with the saturation of the color perceived to belong to the specimen.

The relationship of the three color attributes can be best described in terms of a three-dimensional color space in which all discriminable colors are conceived to be arranged so that neighboring colors differ from one another in each of the three attributes by just noticeable degrees. The numerical scales of the Munsell system, for normal conditions of color matching, bear approximately the following relation to each other when chroma is at /5: 1 Value step = 2 chroma steps = 3 hue steps.

The notation of the Munsell system is written H V/C. as 5R 4/10 which reads "red, four value, ten chroma," or "red four-ten." Because the scales are decimal the notation can be expressed in as small a difference as it is possible to identify. For cotton measurements, value is carried to two decimal places, and chroma to one decimal place in order to express the small color differences in cotton color that are represented in the grade standards.

The relation of the Munsell system to the C.I.E. system is fully covered in a series of papers that appeared in the July 1943 Journal of the Optical Society of America. For historical discussions there are several reports in the December 1940 number of the same journal.

Disk Colorimetry. Disk colorimetry is a very simple and fundamentally sound method of additive colorimetry, suggested years ago by Clark Maxwell. By the use of Maxwell disks—cut with a radial slit so that several may be slipped together with portions of each visible—and a

---

1/ These initials refer to the Commission Internationale d'Eclairage, under whose auspices international standards were adopted in 1931 for colorimetry.

motor on which to spin them at a speed great enough so that there is no flicker, any color that lies in the color solid within the volumes intermediate to the colors of the disks used, may be matched. Precision in matching can be self-taught. An observer has either to make many measurements and use an average, or reduce his scatter to a minimum and use fewer measurements. He can decide for himself when he is able regularly to repeat his readings to a tolerance that is satisfactory for the studies he wishes to make.

Instruments for use in disk colorimetry were developed for use in the United States Department of Agriculture laboratories in the early 1930's and were used on cottons until 1950. Spinning optical parts were incorporated into these instruments in order to avoid spinning either the sample or the disks. A handbook on the method of disk colorimetry, published in 1946, was reprinted in 1958.

C.I.E. Specification. By the C.I.E. method of color notation, results of color measurements are reduced into terms of the standard observer and coordinate system of colorimetry adopted in 1931 by the International Commission on Illumination. The data are expressed as the absolute (X, Y, Z) and fractional (x, y, z) amounts of three imaginary red, green, and blue lights necessary for an imaginary standard observer to match a given sample under a given illuminant. The C.I.E. Y function is set to represent the luminosity, and C.I.E. data are therefore often expressed as Y for luminous reflectance, and as (x, y) for plotting on an (x, y)-mixture diagram. A light source of some sort must be assumed before calculation of C.I.E. data, and that source thereafter becomes the reference point for the data. The spacing on an C.I.E. (x,y)-diagram has little relation to equal color-sense intervals.

Use of C.I.E. data makes it possible to interrelate results of measurements by any instrument or method that has been standardized in terms of C.I.E. The relation of Munsell to C.I.E. has been fully reported in the July 1943 Journal of the Optical Society of America.

Photoelectric Tristimulus Colorimetry. The term "photoelectric colorimetry" may be employed either to designate tristimulus colorimetry or abridged spectrophotometry. For the purposes of the work discussed in this report it is concerned with tristimulus colorimetry in which it is desired to find a source-filter-photocell combination using three or more filters which combine to provide spectral characteristics that duplicate C.I.E. conditions for the standard observer under specified conditions of observation (for usual work these include average background, daylight illumination). No one has yet duplicated perfectly the desired combination but several investigators have obtained combinations suitable for satisfactorily measuring color differences between samples that are spectrally similar.

Any instrument that is to measure color differences as small as those recognized daily by trained inspectors or classers in many lines of commercial color work must have high precision.

The Hunter type of colorimeter used as a basis for the cotton colorimeters discussed in this report employs photodetectors and three filters—

amber, green, and blue—which approach but do not match the spectral distribution curves for C.I.E. (X, Y, Z)-data using daylight for the illuminant as expressed by C.I.E. Illuminant C.

Hunter (R_d, a, b)-coordinates. As reported in (5) the source-cell combinations using the amber, green, and blue filters selected for use by Hunter result in the following approximations for C.I.E. (X, Y, Z):

$$X \doteq 0.80A + 0.18B$$
$$Y \doteq 1.00G$$
$$Z \doteq 1.18B$$

These equations are only approximate because the combinations differ somewhat spectrally from the desired C.I.E. data. As far as is known no importantly better combinations have yet been produced, although by substituting a separate violet in 1.18B, a somewhat better combination is now available.

Because C.I.E. coordinates do not supply a plot representing uniform chromaticity, Hunter very early developed a new relation based on photoelectric tristimulus results that allows color to be plotted to show more uniform spacing than in the C.I.E. diagrams. The early Hunter chromaticity plots were for α, β on a basis of the following equations:

$$\alpha = \frac{A - G}{A + 2G + B}$$
$$\beta = \frac{0.4(G - B)}{A + 2G + B}$$

Later, in developing a direct-reading instrument the filter combinations were adjusted so that subtractions of the light through the filters are made within the instrument and thus avoid mathematical computations by the operator of the instrument. If instrument combinations could have been made that would result in readings in terms of the color attributes of hue, value, and chroma this would have been done. As it is, the best approximation to uniform spacing that the instrument facilities allow, was adopted. For lightness, either a direct-reading of luminous reflectance, R_d, is used, or an L reading, which is related to R_d by a factor fY, 2/ is used to make the steps of the scale more uniform to the eye. If the Munsell value function could have been incorporated into the instrument it would have been used for L, but as it is, fY provides the closest approach to this that seems instrumentally possible at present. On the new direct-reading instrument, chromaticness is expressed in terms of the following (a, b)-coordinates:

$$a \doteq 175\ fY\ (1.02X - Y)$$
$$b \doteq 70\ fY\ (Y - 0.847Z)$$

2/ $fY = 0.51\ [\ (21 + 20Y)/(1 + 20Y)\ ]$

Cartesion coordinates and an origin located at a point representing white (MgO) are used for plotting ±a representing the direction of red-green, ±b representing the direction of yellow-blue.

For the cotton colorimeter the factors R_d and +b are directly measured on the instrument. A measurement of +b relates to the degree of chroma 3/ as long as the hue of the cotton remains the same. The hue is so nearly constant for such a very large proportion of cotton (it is 10 Yellow-Red on the Munsell hue scale) that an instrument based on the two factors of R_d, +b seems adequate for all but those few samples that may be grassy (showing more green than usual) or peculiarly red stained (so that the color becomes more red than usual). Such samples can be measured, but they will not fall into line for chroma as will the cottons of constant hue.

3/ Constant +b represents higher chroma for dark colors than for light colors, but the difference is small for the lightness range of cotton colors. On the cotton colorimeter changes in +b closely approximate changes in chroma, when hue (at 10 Yellow-Red) is held constant.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington 25, D. C.

A NEW COTTON TRASHMETER

A report by Harvin R. Smith, Cotton Marketing Specialist, Standardization Section, Standards and Testing Branch, Cotton Division, before the 1960 Cotton Research Clinic, Asheville, N. C. — May 31, 1960

The Department of Agriculture has been interested in the precise measurement of color and of the amount of trash on the surface area of cotton samples for many years in connection with its cotton grade standards program. A visual disk colorimeter, successfully developed about 1929, was used until 1950 when it was replaced with an electronic instrument.

It may be of interest to note that emphasis on early electronic instrumentation was directed primarily toward measurement of trash, and that work on an electronic colorimeter evolved later. In the period 1938 to 1941, D. Nickerson and C. M. Asbill, Jr. 1/ designed and built a device called a "grade scanner" which employed a moving spot of light, about 1/64" in diameter at slow speed, 1/4" in diameter at fast speed, which scanned a path across the face of cotton samples in a box of grade standards. The light and dark areas encountered by the spot of light were directed to a photocell, the signal was amplified, and automatically recorded on a chart. The device was successful in providing a record of the light and dark areas across the sample, but the amount of time required to make readings with the small spot was about 2 minutes per sample for scanning a single path, and it was also a long and laborious process to interpret the charts. Work began on automatic interpretation of chart results, but was interrupted by the war in 1941.

During the war years so many advances were made in electronic techniques that work on the scanner was suspended until advantage could be taken of these newer techniques. Meanwhile, color measurement was proving to be such a useful aid that visual methods were no longer adequate, and work began on the development of an automatic, self-standardizing, electronic colorimeter. The Nickerson-Hunter Cotton Colorimeter that came into use in 1950 provided the first automatic device we know of that would measure cotton color rapidly and accurately. Following successful development of this cotton colorimeter, attention again was turned to a scanner for providing information about trash on the surface of cotton samples. It was intended that this trash scanner would be a companion to the colorimeter, that it would operate rapidly enough to measure the surface trash on every sample of cotton put into grade standards boxes, just as color is measured for every sample.

1/ Then on the staff of USDA's laboratory at Clemson, now with North Carolina State School of Textiles.

Until very recently the Shirley Analyzer has provided the only practical method by which the foreign matter content of lint samples could be measured. This device is slow and expensive, and although it does a fairly good job of physically separating lint from foreign matter, it does not evaluate leaf or trash content in a sample of cotton as the classer does. A surface measure of leaf content would be more useful in our standards work to help maintain uniformity of grade standards than a measurement of trash by weight of nonlint for each bale, as given by the Shirley Analyzer.

By 1954, when attention again was turned to trash measurements, television scanning methods were well known and were beginning to be applied in many commercial fields. After investigating the practicability of employing such methods in a cotton trashmeter, performance specifications for a device were developed. Specifications provided that the instrument be designed on the principle of television scanning, with a signal utilization system to provide two readings, one a measure of the total area of trash (dark areas) on a given surface, the other, a reading to provide a measure of the number of trash (dark) particles on a given surface, provision to be made for adjustment of the reflectance threshold level at which separation would be made of "trash" or "dark" particles against the lighter background color of lint cotton, that it should scan an area about 4" x 4", and measure particles as small as 0.01 inch with a precision of $\pm$ 0.005 inch.

In 1956 a contract was let to the Outlook Engineering Corp. of Alexandria, Virginia, and they built and delivered an instrument employing a Vidicon tube as the sensing device. Many difficulties were encountered in keeping this instrument calibrated; it lacked stability, was sensitive to background color and in fact, proved unsuitable for our use. Briefly, it would not measure what we thought it should without employing an electronics technician to operate and maintain it. With this experience, and at the request of the contractor, specifications were modified to allow use of an optical-mechanical scanner instead of a Vidicon tube. The result could be called a sophisticated, modernized version of what had been the original Nickerson-Asbill idea.

This instrument, the Outlook Cotton Trashmeter to be discussed, was delivered about a year ago and was accepted (June 1959) after tests showed that it met the service requirements of the contract. Evaluation has continued since then. The instrument scans 1,000 lines per frame at a speed of 345 lines per second. The width of scan is .004 inch. It requires about three seconds to scan a 4" x 4" sample of cotton as compared with the almost "instantaneous" scan provided by the Vidicon tube. Results are indicated on two meters that are located on the top of the machine at the back. One meter indicates the fraction of the total area of a sample surface occupied by the dark areas of trash, and the other gives an indication of the relative number of particles (actually it counts the number of times the scanning spot crosses a light-to-dark boundary). A compensating circuit automatically adjusts for imperfections in illumination. The level of reflectance at which the dark particles will be counted is adjusted by a threshold control. The shaping and modification of the signals passing through the threshold level eliminate the effects of background color, as well as variations in the level of reflectance provided by the trash particles themselves.

A close view of the working surface of the trashmeter is shown in figure 1. This illustrates the position of the sample window and the two meters above it on which results are indicated for "Percent Area" and "Relative Count."

One of the first and most important problems with the instrument was the development of a calibration method that would enable us to maintain a uniform level of results. Changes in threshold levels occurred through the aging of illuminating lamps, changes in tubes, and in the accumulation of dust on the surfaces of the scanning mirrors. To check the calibration, a series of standard papers was prepared, each paper having different sizes and numbers of black dots, some on different background colors. These papers were somewhat of a makeshift standard, but they have served to help in making the initial evaluations of the instrument.

Figure 2 and table 1, illustrate the precision of the instrument as measured by successive readings over a 30-day period on this series of calibration papers. While the precision reported is sufficient for a first instrument, it leaves a great deal to be desired in a perfected instrument.

Between area and count readings a closer correlation exists than we wish, but through some redesigning it seems certain that this can be taken care of more adequately in a second instrument. In contrast to results obtained on the first model in which a Vidicon tube was used, differences in background color no longer influence meter readings, as shown by measurements for papers numbered 2, 3, and 4. These papers have the same number and size of dots, but they vary in background color within the color range of American cottons. Results for paper No. 6, which contains six short thin lines, show the effect of sample orientation on the results. This effect is of no major consequence with cotton if leaf areas are randomly oriented, but it might be an important consideration in samples containing grass, bark, or bits of stems if there were any tendency toward parallelization of the trash particles.

Figure 3 shows typical results for a series of repeated measurements on a set of grade standards. These are repeated measurements on an identical set of samples that were made over a period of approximately one month. Similar measurements made over many months, follow the same pattern. Because of the close correlation between area and count measurements, results are illustrated in figure 3 for count only. Data for area as well as count are reported in table 2. The standard deviation reflects a combination of the variability introduced both by the instrument and by the sample. However, even with this degree of variation there is a fairly sharp distinction between measurements for the various grades tested.

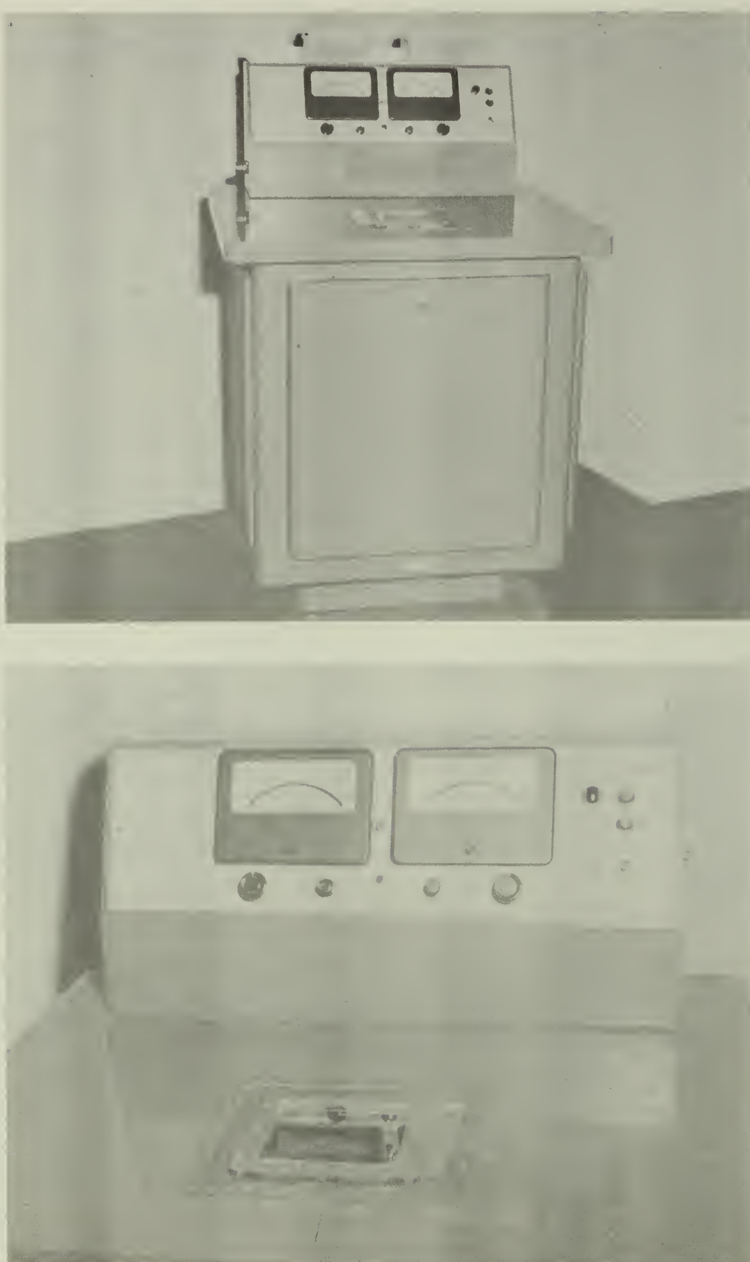


FIGURE 1.--THE OUTLOOK COTTON TRASHMETER.

A full view of the instrument is shown on the top and on the bottom is shown a closeup of the working surface.

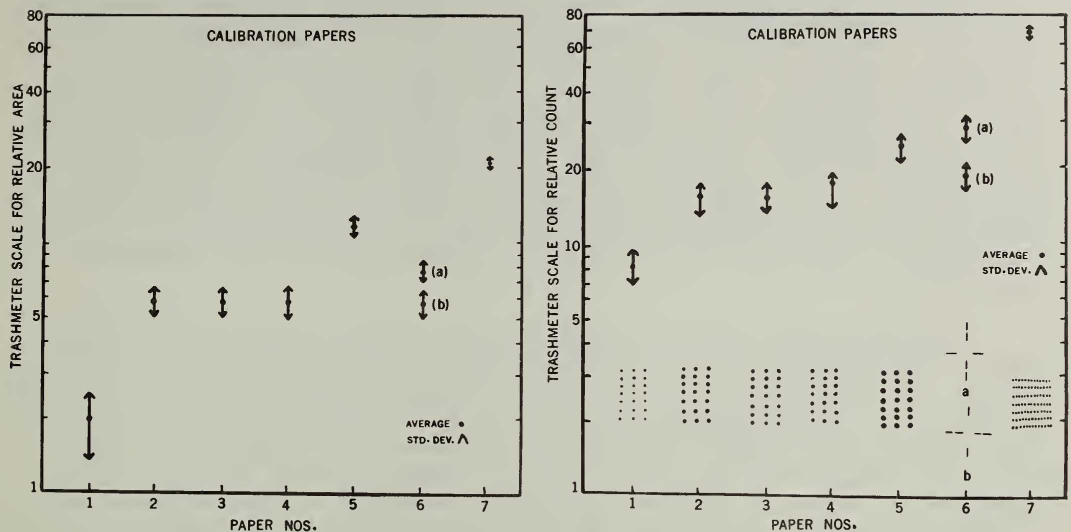


FIGURE 2.--PRECISION OF MEASUREMENTS ON OUTLOOK COTTON TRASHMETER.

Averages, ± one standard deviation, of measurements on calibration papers; for relative area (left) and for relative count (right). Measurements repeated over a 30-day period. A sketch of the papers used in this experiment is shown in the figure on the right; papers numbered 2, 3, and 4 have the same number and size of dots, but different background colors.

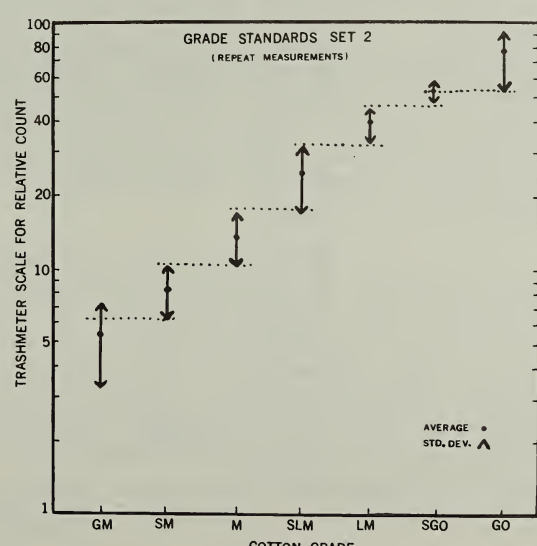


FIGURE 3.--PRECISION OF MEASUREMENTS FOR OUTLOOK TRASHMETER ON IDENTICAL COTTON SAMPLES.

Averages, ± one standard deviation for 30 repeat readings taken over a period of one month on each of 6 samples in each grade.

Figure 4 illustrates test results obtained on many samples taken from the same bales, as measured on the Outlook Trashmeter and on the Shirley Analyzer. For this test 30 samples were selected throughout each of several grade standards bales; tests were made on both the Trashmeter and on the Shirley Analyzer. The variation, involving different samples but limited to the same bale, is slightly greater than it is for repeated readings on the same samples. The precision of the Shirley Analyzer measurements seems somewhat better on these samples than the precision of the Trashmeter measurements, but in partial explanation it should be noted that the Shirley Analyzer uses a much larger sample, also that not as many different bales were used in tests made with the Shirley Analyzer as with the Trashmeter (table 3).

During the 1959 crop year Trashmeter and Shirley Analyzer tests were made on all samples collected for our Annual Fiber and Processing Quality Survey. 2/ This survey included several hundred spinning test lots from all of the major cotton producing areas in the United States collected at periodic intervals throughout the harvesting season. For inclusion in this report test results have been selected for 25 samples taken at random from each grade. Means and standard deviations, computed for measurements made on these samples on the Outlook Trashmeter and on the Shirley Analyzer, are illustrated in figure 5. These results show that the Trashmeter measurements provide a sharper distinction between grades than measurements made on the Shirley Analyzer, for there seems to be less overlap between grades as measured on the Trashmeter than for those measured with the Shirley Analyzer (table 4). One may conclude from this that the Trashmeter sees cottons more like the classer does.

These results are encouraging and we believe that refinement of test procedures and calibration techniques should make it possible to improve on the precision reported. During the coming season evaluation of the instrument will be continued in greater detail. It is confidently expected, once we adopt suitable scale levels for reporting measurements, that this instrument will prove a valuable companion to the colorimeter in our standards and cotton classing programs. This instrument could also be useful to those who are interested in obtaining a rapid measure of relative trash content without destroying the sample.

In closing, we wish to mention that we also are evaluating the small Fractionator recently developed by the ACCO Laboratories at Houston, Texas, and are most enthusiastic about its possibilities. 3/ From figure 6 it can be seen that the preliminary measurements made in our laboratories on this instrument agree closely with those made on the Shirley Analyzer. This device has been greatly improved since the original model was built, and we are awaiting receipt of an improved model with considerable interest, for we plan to run parallel tests during the 1960 season on it, on the Outlook Trashmeter, and on the Shirley Analyzer.

2/ "Annual Cotton Quality Survey, Summary of Results of Fiber and Processing Tests from Selected Market Areas, Crop of 1959." United States Department of Agriculture, AIB No. 227, April 1960.

3/ Dr. Earl E. Berkley. "Progress of Instrumentation for Selecting Cotton for Specific End Uses." Paper presented at A.C.M.I. Open House, April 15, 1959, Clemson, S. C.

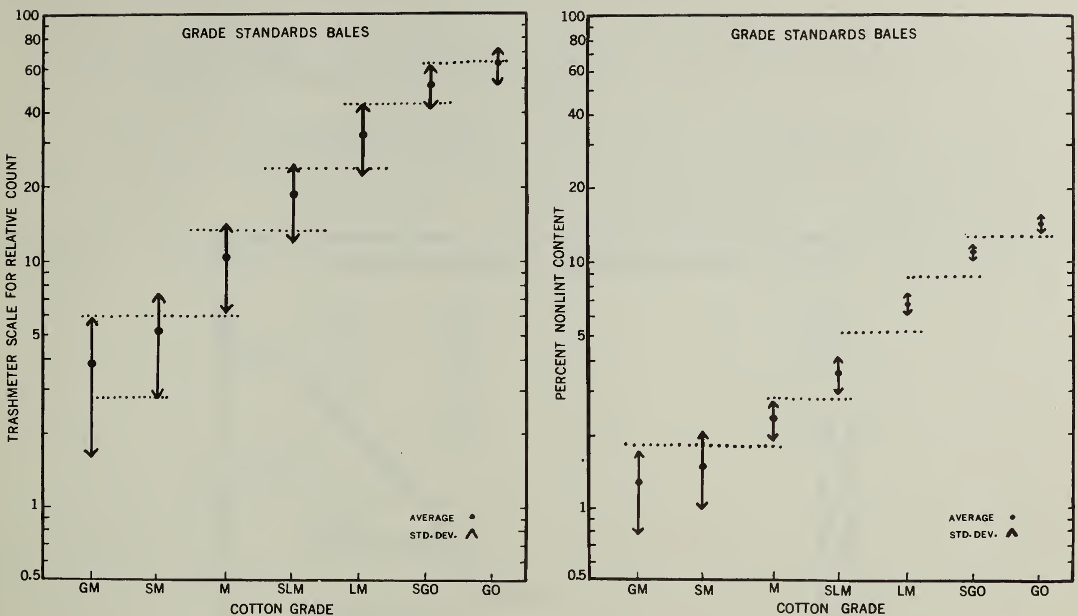


FIGURE 4.--VARIABILITY OF MEASUREMENTS ON OUTLOOK TRASHMETER COMPARED WITH VARIABILITY ON THE SHIRLEY ANALYZER FOR SAMPLES WITHIN THE SAME BALES.

Average, ± one standard deviation, for 30 samples from each of several bales of cotton. (Trashmeter, 50 bales; Shirley Analyzer, 15 bales)

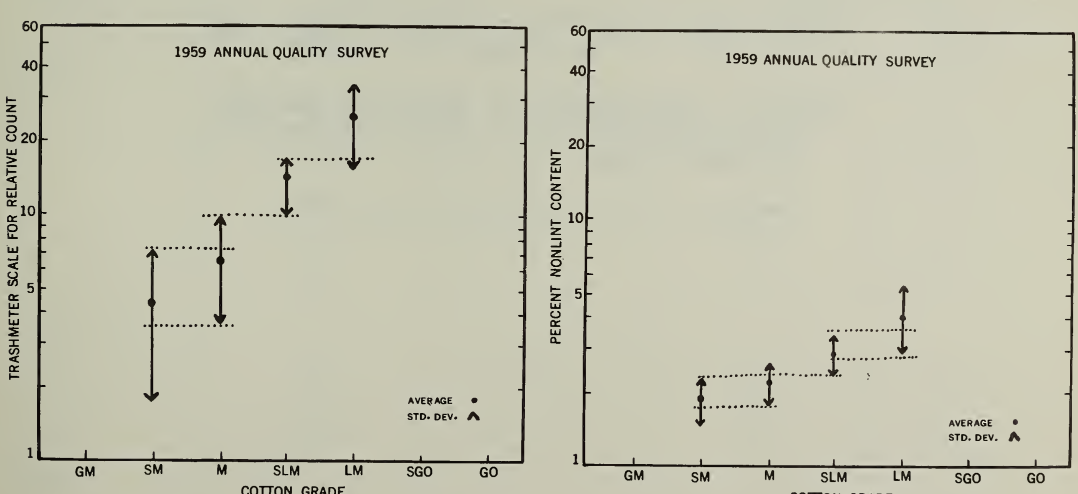


FIGURE 5.--VARIABILITY OF MEASUREMENTS ON OUTLOOK TRASHMETER COMPARED WITH VARIABILITY ON THE SHIRLEY ANALYZER FOR SAMPLES CALLED THE SAME GRADE.

Average, ± one standard deviation, for 25 samples of each grade, selected at random from 1959 Annual Quality Survey samples.

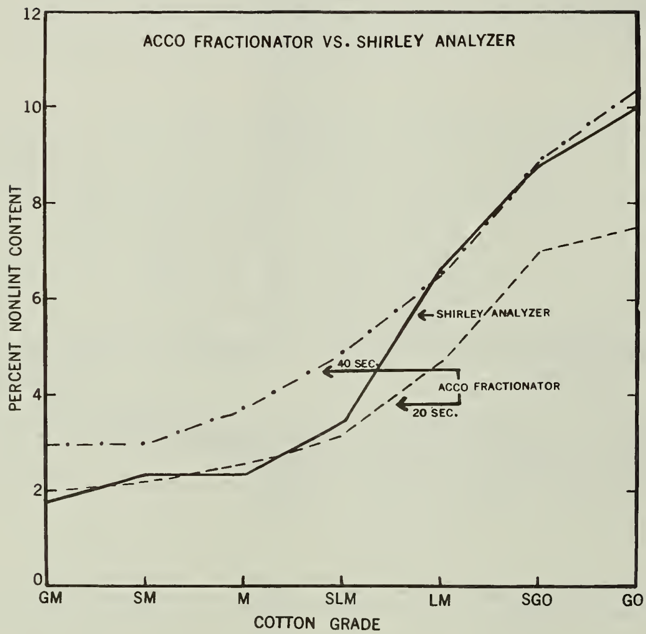


FIGURE 6.--MEASUREMENTS OF NONLINT ON THE ACCO FRACTIONATOR AND ON THE SHIRLEY ANALYZER FOR THE SAME COTTONS.

Averages for five cottons of each grade.

TABLE 1.--INSTRUMENT VARIATION OF OUTLOOK TRASHMETER.

Averages and standard deviations of 30 repeat measurements taken over a 30-day period on standard calibration papers

Item	Calibration Papers			Results			
	Description			Relative Area		Relative Count	
Paper No.	No. Dots	Size	Prod. No.	Avg.	Std. Dev.	Avg.	Std. Dev.
1	21	1/32"	3831	2	± 0.6	8	± 1.2
2	21	3/64"	3831	6	± 0.9	15	± 1.9
3	21	3/64"	3832	6	± 0.8	15	± 1.6
4	21	3/64"	3833	6	± 0.9	17	± 1.9
5	21	1/16"	3831	12	± 1.3	24	± 2.6
6 a	6	Thin Lines 1/32" x 1/4"	3832	8	± 0.8	29	± 2.0
b	(Same as 6a Oriented 90°)			6	± 0.7	19	± 2.0
7	91	3/64"	3831	22	± 1.5	71	± 3.9

TABLE 2.--INSTRUMENT VARIATION OF OUTLOOK TRASHMETER ON IDENTICAL COTTON SAMPLES.

Variation for 30 repeat measurements on a set of cotton standards taken over a 30-day period

Grade	Relative Area		Relative Count	
	Average	Std. Dev.	Average	Std. Dev.
White				
GM	1.1	± 0.5	5.6	± 2.3
SM	2.5	± 0.7	8.5	± 2.1
M	3.7	± 0.9	13.9	± 3.1
SLM	6.9	± 1.7	25.4	± 5.6
LM	11.3	± 1.7	38.8	± 5.4
SGO	17.1	± 2.5	53.7	± 6.5
GO	23.3	± 4.4	77.9	± 13.4
Spotted				
SM Sp	3.4	± 1.1	13.1	± 4.0
M Sp	5.4	± 1.6	19.7	± 5.9
SLM Sp	11.9	± 2.3	38.7	± 7.9
LM Sp	22.4	± 3.5	67.6	± 9.8
Tinged				
SM Tg	2.3	± 1.1	10.1	± 4.4
M Tg	6.7	± 1.5	24.0	± 6.2
SLM Tg	12.3	± 3.1	42.1	± 11.4
LM Tg	20.7	± 3.0	65.3	± 10.8

TABLE 3.--VARIABILITY OF MEASUREMENTS ON OUTLOOK TRASHMETER VS. SHIRLEY ANALYZER.

Average test results for 30 samples from several grade bales of cotton (Trashmeter, 50 bales; Shirley Analyzer, 15 bales)

Grade	Outlook Trashmeter				Shirley Analyzer	
	Relative Area		Relative Count		Nonlint Content-Percent	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
GM	0.8	± 0.6	4.0	± 2.4	1.2	± 0.4
SM	1.0	± 0.7	5.4	± 2.5	1.5	± 0.5
M	2.9	± 1.6	10.8	± 4.5	2.3	± 0.4
SLM	5.1	± 2.5	19.0	± 6.6	3.5	± 0.6
LM	10.8	± 3.6	35.3	± 10.7	6.6	± 0.7
SGO	16.4	± 4.7	55.5	± 12.2	10.7	± 0.7
GO	21.8	± 4.5	68.6	± 12.0	14.2	± 1.0

TABLE 4.--VARIABILITY OF MEASUREMENTS ON OUTLOOK TRASHMETER VS. SHIRLEY ANALYZER.

Averages and standard deviations on 25 samples selected at random for each grade from 1959 Annual Quality Survey

Grade	Outlook Trashmeter-Count				Shirley Analyzer-Percent	
	One Reading		Two Readings		Nonlint Content-Percent	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
SM	4.7	± 3.2	4.8	± 3.1	1.9	± 0.4
M	6.8	± 3.4	6.8	± 2.7	2.2	± 0.4
SLM	13.8	± 3.7	14.7	± 3.8	2.9	± 0.5
LM	26.7	± 11.3	24.8	± 10.1	4.0	± 1.2

UNITED STATES DEPARTMENT OF AGRICULTURE * - *
Agricultural Marketing Service
Washington 25, D. C.

A NEW LOOK AT COTTON QUALITY RELATIONSHIPS

Based on Statistical Studies of Cottons, 1946-59, that include both classification and laboratory tests

A report by Franklin E. Newton, Cotton Technologist, Standardization Section, Standards and Testing Branch, Cotton Division, before the 1960 Cotton Research Clinic, Asheville, N. C. — June 2, 1960

INTRODUCTION

We need to define clearly those properties of cotton which are significantly related to its use-value. We need fast, repeatable, precise methods for measuring these properties. We need to define and measure the properties required for efficient spinning and weaving to obtain high quality in manufactured products. We must have a better understanding of the relationships between the properties of the raw material, their manufacturing performance, and their contribution to finished product quality.

In this report we undertake to make a contribution to the understanding of quality evaluation by reporting relationships between available fiber property measurements and various tests of spinning performance and product quality. We do this by examining the relationships between the fiber property measurements and processing and spinning tests that have been made by the Cotton Division since 1946.

Tests currently made in the USDA cotton laboratories either routinely, or for special purposes, are listed in table 1. Practically all of them are made on every sample submitted for a spinning test. Data on some of these properties, particularly on short fibers and ends-down at spinning are at present virtually unavailable. We realize that other fiber properties may be important that we do not now measure, but these we either do not yet know how to measure, or how to measure satisfactorily.

Cotton quality, as an overall measure, has never yet been defined satisfactorily; usually one factor of quality receives particular emphasis. Sometimes yarn strength is emphasized, sometimes it is yarn appearance, sometimes manufacturing waste. Each of these is dependent on many measurable raw cotton properties. In our laboratory testing program (1,2)[1/] we have considered the following five measures as indicative of processing and product quality: (1) percent manufacturing waste, (2) yarn strength, (3) yarn appearance, (4) color of bleached yarn, and (5) color of dyed yarn. We report here the relation of each of these five measures to the properties we have tested. These results are in addition to those included in the Webb-Richardson series of reports published since 1945, for which a full list is contained in Webb's most recent report (3).

1/ Underscored figures in parentheses refer to Literature Cited.

Table 1.--List of tests currently being made in USDA cotton classing rooms and laboratories, either routinely, or for special purposes

Property Measured	Type of Test	Method of Determination
	TESTS OF RAW COTTON	
Length	Staple	Classer's Pull
	Length, and Length Distribution e.g., UQL, C.V., Short Fibers	Suter-Webb Sorter
	Length, and Length Uniformity e.g., UHM, UR, Short Fibers	Fibrograph
Color	Grade, Raw Stock	Visually by Classer
	Color, Raw Stock	Cotton Colorimeter
	Color, Cleaned Lint	Cotton Colorimeter
Foreign Matter	Grade, Raw Stock	Visually by Classer
	Nonlint Content	Shirley Analyzer
	" "	Fractionator (ACCO)
	Relative Surface Leaf Area and Count	Trashmeter
Strength	Flat Bundle of Fibers 1/	Pressley, 0 and 1/8" Gauge
Fineness	Linear Density (wt/in)	Array Method
	Resistance to Air Flow	Micronaire and Similar Commercial Instruments
Maturity	Cell Wall Development	Array Method-Microscopic
	" " "	Causticaire
Neps	Count	Visual
Physical-Chemical	Percent Soluble Sugar	Chemical-Colorimetric
	Acid-Alkiline	pH Meter
	Moisture Regain	Oven Test
	Moisture Content	Moisture Meters
	TESTS DURING PROCESSING	
Waste	Percent, Raw Stock	Weight at Picker and Card
Neps	Count in Card Web	Visual
Performance	Ends-Down	No./2,000 Spindle Hours
	Spinning Potential	No./200 Spindle Hours
	TESTS OF MANUFACTURED PRODUCT	
Strength	Skein Test on Grey and Merc. Yarn	Pendulum Skein Tester
	Single Strand, Grey Yarn	Automatic Pendulum Tester
Irregularity of Yarn	Appearance	Visual, against ASTM Yarn Appearance Standards
	Count of Imperfections	Imperfection Counters
Color	Color-Grey, Bleached, and Dyed Yarn	Color Difference Meter
Luster	Luster, Grey and Merc. Yarn	Lustermeter

1/ Preceded by Chandler bundle test, developed by Dr. E. E. Chandler in 1926 for use in the Cotton Division's early testing program.

SOURCE OF COTTONS USED IN TESTS

All analyses in this report are based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1946-58 (4-17) and on test results in our files for full ranges of grades and staples in 1956 and 1959-60 studies of standards bales. 2/

Sampling. For the Annual Quality Studies, classer's samples of the same grade and staple are assembled at the U. S. Department of Agriculture classing offices from selected commercial gins at different intervals during the harvesting season. These samples represent the modal grade and staple at the time of selection and are composited into 6- to 8-pound spinning lots; therefore, the range in the qualities of spinning lots for each year is not the same. Because of this varied distribution, correlation coefficients are not necessarily comparable from year to year.

For the studies of standards bales, each spinning lot represents an individual bale purchased by the U. S. Department of Agriculture for use in the grade and staple standards. The 1956 study of grade standards consists of a complete range of white and colored grades but the 1959 study reported here includes results for white grades only. The 1959 study of staple standards consists of a complete range of staples for the American Upland scale.

METHOD OF PROCESSING

Small-scale spinning tests, made at the Cotton Division's spinning laboratories according to previously developed standard procedures, provide the fiber and processing results for each study, 1946 through 1958. Only the processing results from lots carded at 9 1/2 pounds per hour are analyzed in this paper.

From 1946 to 1949, all staples were carded at 9 1/2 pounds per hour using the same organizational setup in the spinning laboratory. From 1950 to date, only the medium staples were carded at this rate. Even though the range of staples varied considerably for some studies, all cottons covered in this report were processed at the same rate and with essentially the same standard procedures.

METHOD OF ANALYSIS

Fast and economical statistical analysis of a large amount of data, accumulated over the past several years, has been made possible through use of electronic data processing equipment.

During the past two years 20 complete statistical studies have been made that include approximately 5,000 spinning lots and cover nearly all tests made in the years 1946-58. These studies have resulted in over 20,000 simple correlations. This number is large because every measured

---

2/ Since 1958 full fiber and spinning tests are routinely made on all bales bought for use in grade and staple standards.

property was purposely included as a variable, and the computer automatically calculated simple correlation coefficients for each variable. These simple correlation coefficients have been obtained for use with a computer program designed to provide multiple correlation coefficients, beta values, partial correlation coefficients, and regression equations. By use of this program, any number of variables up to a total of eight can be selected and the simple correlations for them can be fed back to the computer in order to obtain statistical values for the multiple relationships. Use of electronic equipment has thus increased our pace considerably in evaluating fiber and spinning properties.

RESULTS

Variation in Quality Factors Explained

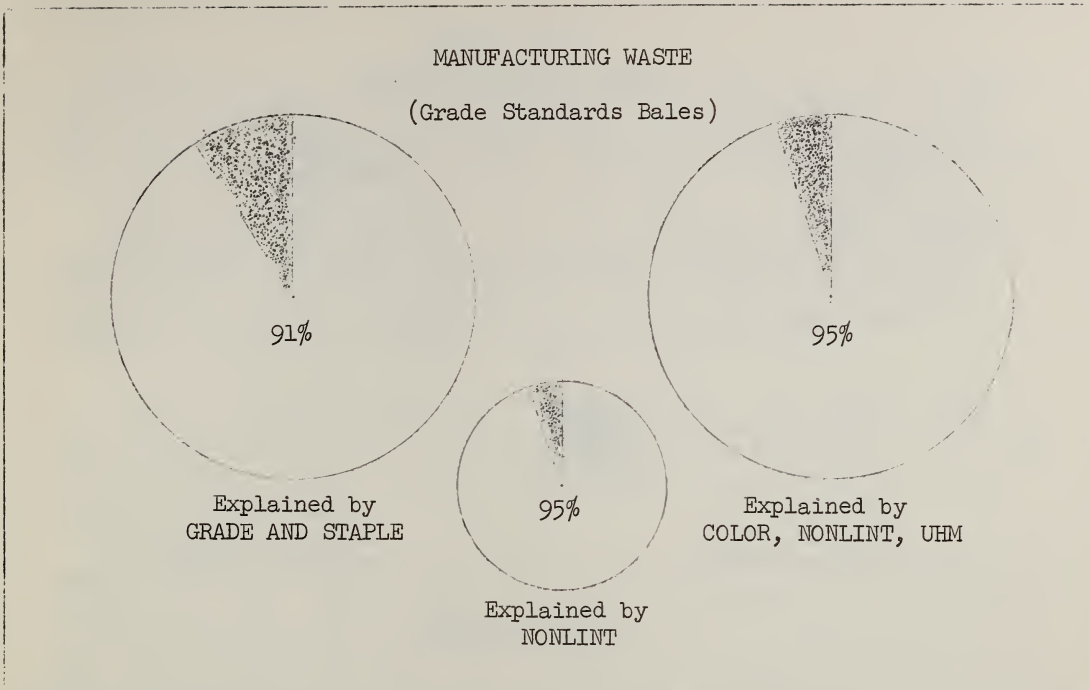
Throughout this report variation is explained for five selected cotton quality factors in terms of parallel sets of measures: (1) classer's grade and staple; (2) color, Shirley Analyzer nonlint, and Fibrograph UHM (the laboratory measures most nearly equivalent to grade and staple); (3) a single fiber property found important in contributing to the total variation that is explained; (4) this single property, added as a supplement to classing and laboratory measures, when its addition significantly increases the explained variation.

The variation reported in figures 1 to 5 is in terms of percent variance, obtained by squaring the correlation coefficients for each study and averaging them. These average results are presented to you today. We expect to publish details for the individual studies, including additional related data, in the very near future.

Manufacturing Waste, Figure 1. When the cottons studied are distributed over a complete range of grades, the variation in manufacturing waste explained by the classer's grade and staple is 91%, by laboratory measures of color, nonlint, and UHM, 95%; by the one measure of Shirley Analyzer nonlint, 95%.

When the cottons studied are restricted to modal grades and staples, as in the Annual Quality Studies, the variation in manufacturing waste that is explained decreased sharply; 45% is explained by the classer, 62% by the laboratory tests of color, nonlint, and UHM, and 55% by the single test of Shirley Analyzer nonlint.

Yarn Strength, Figure 2. For cottons distributed over a complete range of staples, the variation in yarn strength explained by classer's grade and staple is 81%, by laboratory measures of color, nonlint, and UHM, 85%, by fiber strength (Pressley 1/8" gauge), 76%. Adding fiber strength as a supplementary measure to the classer's grade and staple, and to the laboratory measures of color, nonlint, UHM, increases the variation explained to 88% and 90%, respectively.



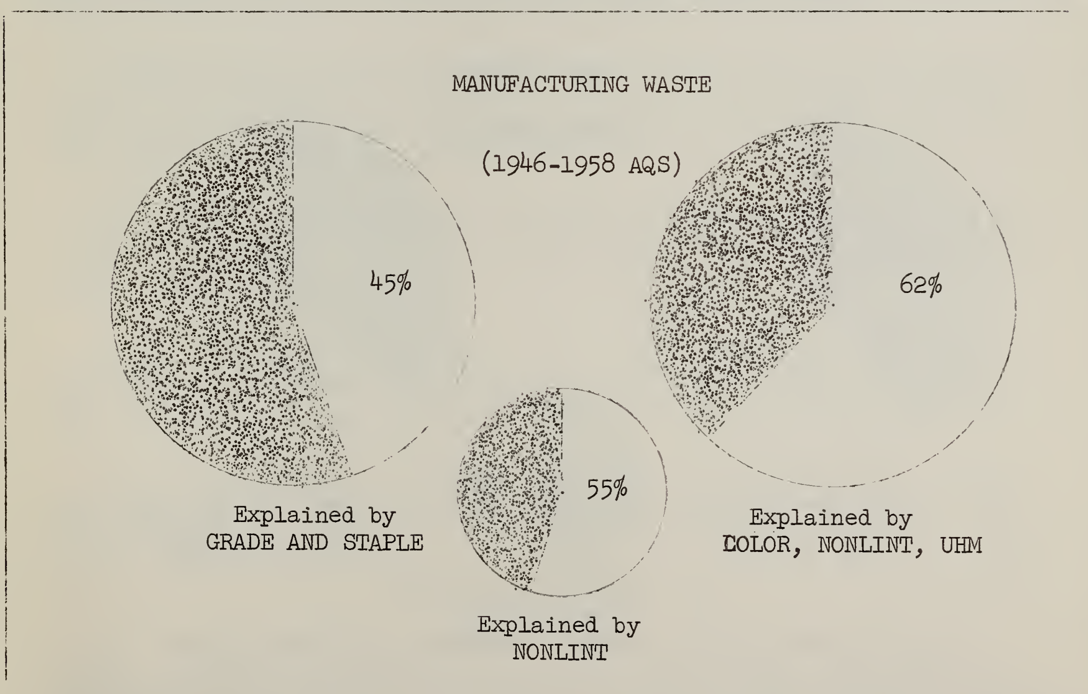


FIGURE 1.--VARIATION IN MANUFACTURING WASTE EXPLAINED BY GRADE AND STAPLE; BY COLOR, S. A. NONLINT, AND UHM; AND BY S. A. NONLINT ONLY.

Based on test results for 1956 and 1959-60 studies on grade standards (above), and on samples in Annual Quality Studies, 1946-58 (below).

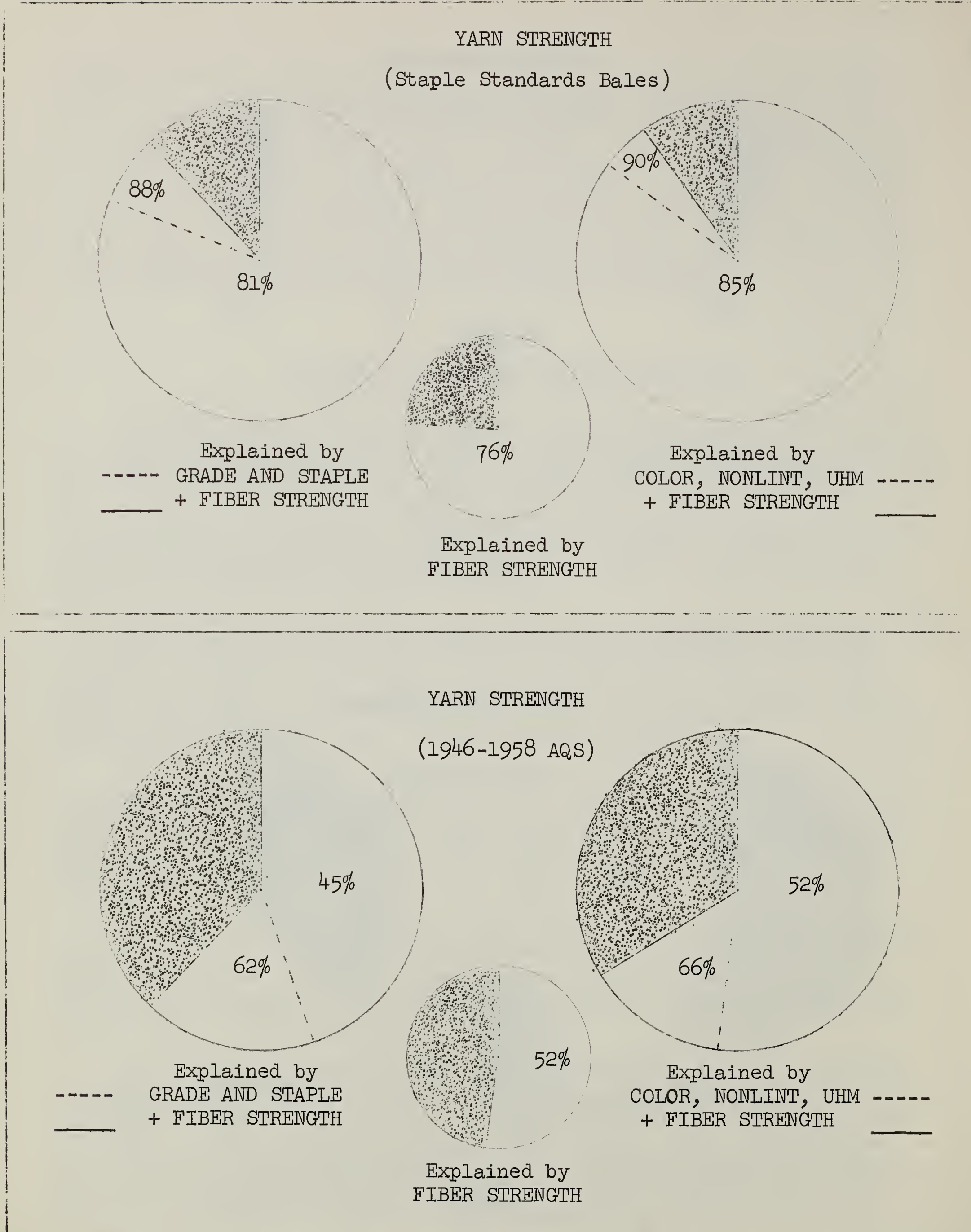


FIGURE 2.--VARIATION IN YARN STRENGTH (22s) EXPLAINED BY GRADE AND STAPLE; BY COLOR, S. A. NONLINT, AND UHM; BY FIBER STRENGTH ADDED TO EACH; AND BY FIBER STRENGTH ONLY.

Based on test results for 1956 and 1959-60 studies on staple standards (above), and on samples in Annual Quality Studies, 1946-1958 (below).

When the cottons studied are restricted to modal grades and staples, the variation in yarn strength explained by grade and staple is 45%, by laboratory measures of color, nonlint, UHM, 52%, and by fiber strength alone, 52%. Including fiber strength (Pressley 1/8" gauge) with the above combinations, increases the variation explained to 62% and 66%.

Yarn Appearance, Figure 3. For cottons distributed over a complete range of grades, variation in yarn appearance explained by grade and staple is 28%, by laboratory measures of color, nonlint, UHM, 31%, by Micronaire alone, 32%. Adding Micronaire to the above combination of variables increases the variation explained to 43% and 46%.

When the cottons are restricted to modal grades and staples, variation in yarn appearance explained by classer's grade and staple is 8%, by laboratory measures of color, nonlint, UHM, 12%, by Micronaire alone, 22%. Adding Micronaire to the above combinations increases the variation explained to 26% and 30%.

As shown by these results, neither classification nor laboratory measures of color, nonlint, and UHM, even when supplemented by Micronaire, explain much about yarn appearance. The range of Micronaire readings for samples used in these tests is restricted. If a wider range were used, then perhaps Micronaire could explain more variation in yarn appearance; unpublished data in our files indicates that as Micronaire readings decrease from around 3.0, yarn appearance rapidly decreases.

Color of Bleached Yarn, Figure 4. For cottons distributed over a complete range of grades, variation in color of bleached yarn explained by grade and staple is 69%, by laboratory measures of color, nonlint, UHM, 72%, by raw stock color alone, 67%.

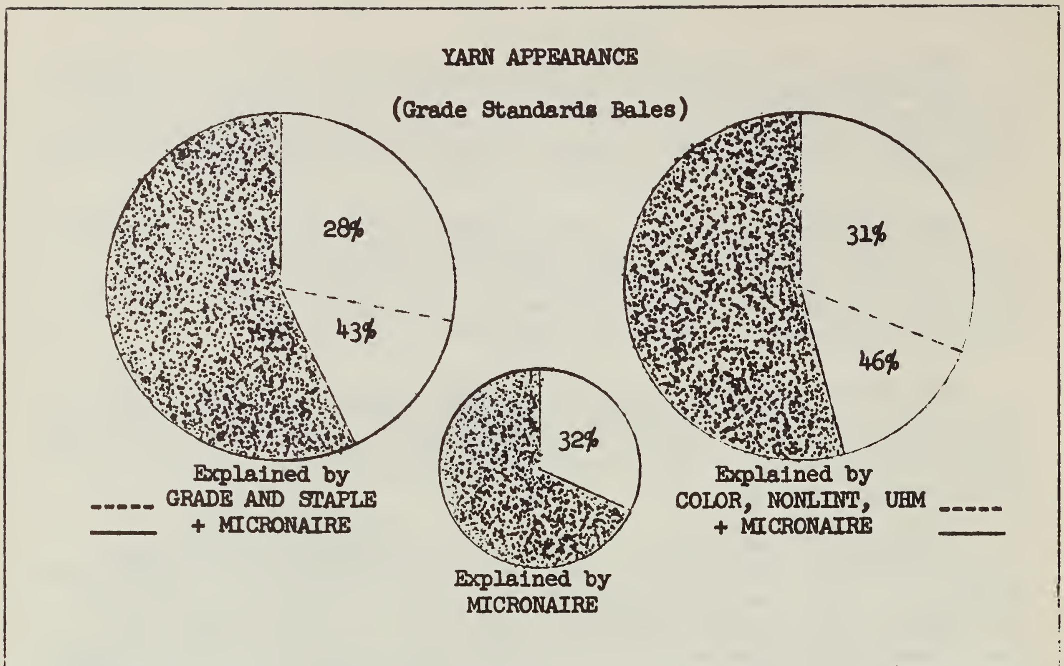
For the more limited range of grades in the Annual Quality Studies, the variation in the color of bleached yarn explained by grade and staple is 25%, by laboratory measures of color, nonlint, UHM, it is 24%, by raw stock color alone, 18%.

Color of Dyed Yarn, Figure 5. For cottons distributed over the entire range of white grades, variation in color of dyed yarn explained by grade and staple is 76%, by laboratory measures of color, nonlint, UHM, 75%, by raw stock color alone, 74%.

For the more restricted range of grades, variation in color of dyed yarn explained by grade and staple is 34%, by laboratory measures, 41%, by raw stock color alone, 28%.

Analysis of Trends

To compare trends and relative levels of classing and laboratory results, regression equations for the data were studied. All years were included, but to simplify the diagrams to be presented, only the results for every sixth year are included in figures 6 to 11.



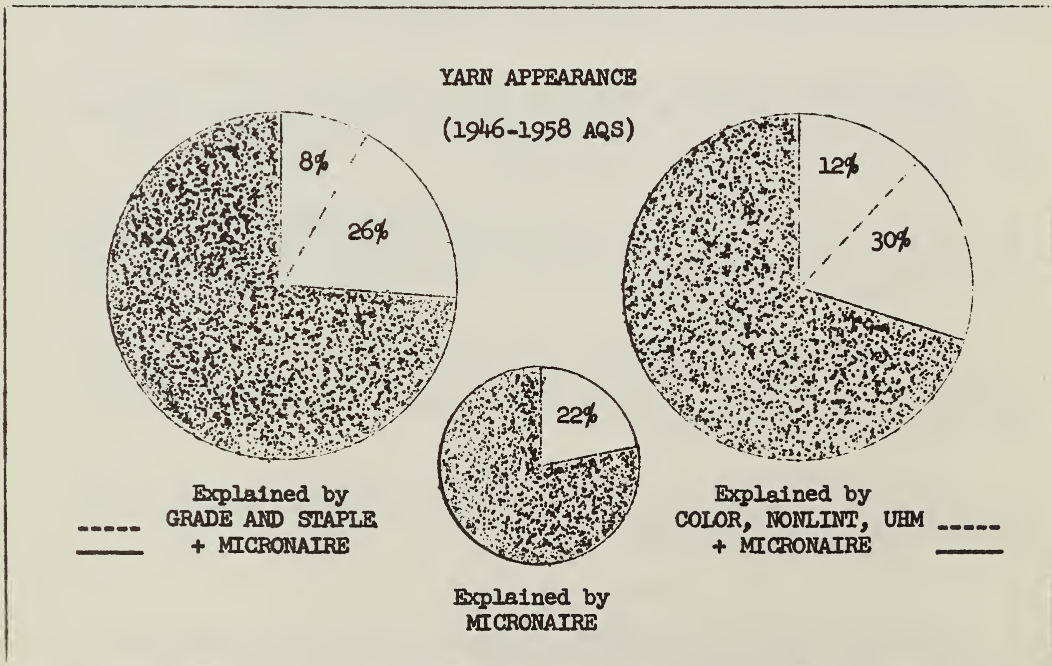
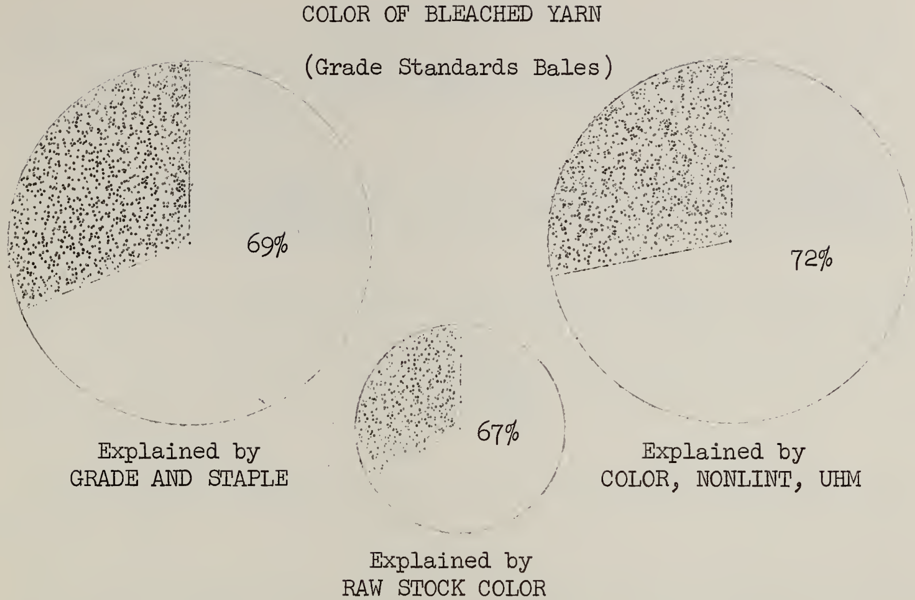


FIGURE 3.--VARIATION IN YARN APPEARANCE (22s) EXPLAINED BY GRADE AND STAPLE; BY COLOR, S.A. NONLINT, AND UHM; BY MICRONAIRE ADDED TO EACH; AND BY MICRONAIRE ONLY.

Based on test results for 1956 and 1959-60 studies on grade standards (above), and on samples in Annual Quality Studies, 1946-58 (below).



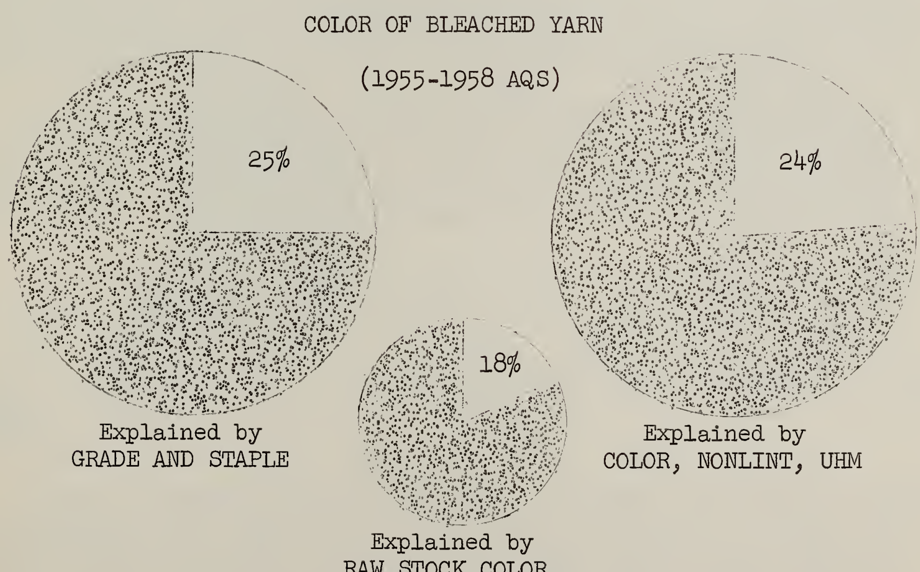
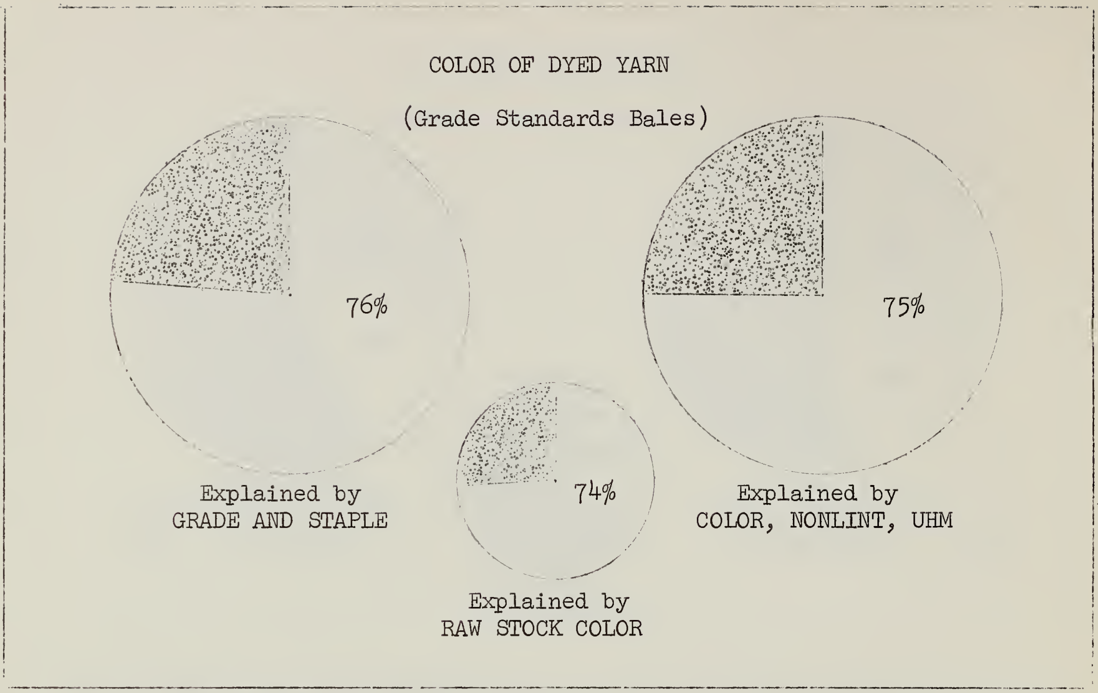


FIGURE 4.--VARIATION IN COLOR OF BLEACHED YARN EXPLAINED BY GRADE AND STAPLE; BY COLOR, S.A. NONLINT, AND UHM; AND BY RAW STOCK COLOR (R_d and +b) ONLY.

Based on test results for 1956 and 1959-60 studies of grade standards (above), and on samples in Annual Quality Studies, 1955-58 (below).



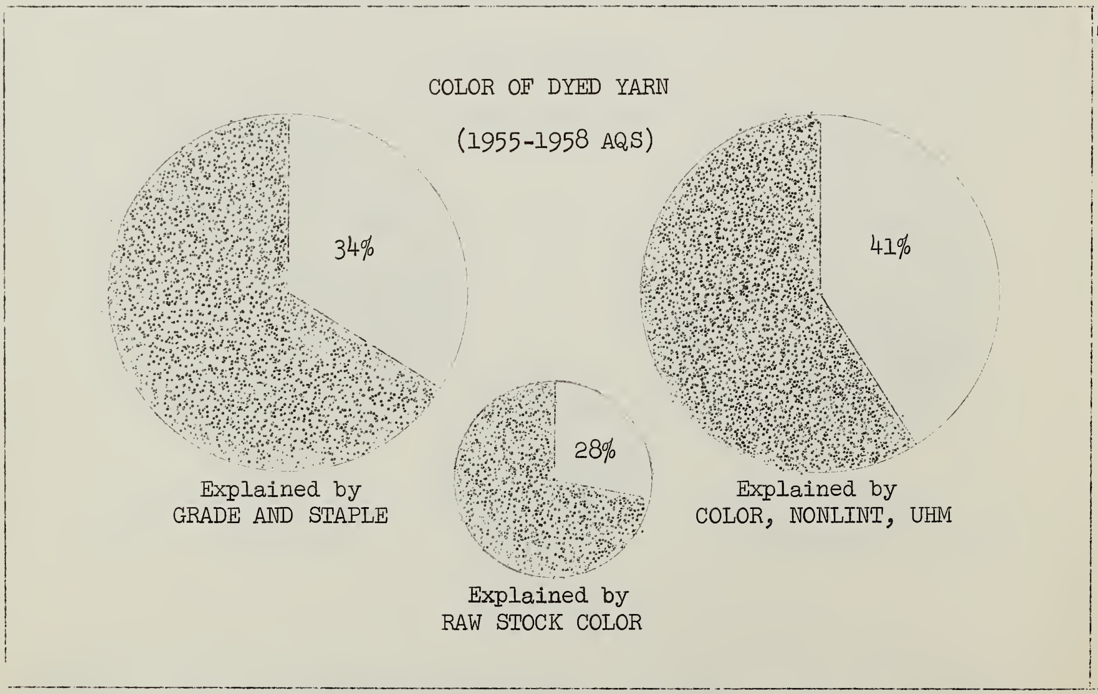


FIGURE 5.--VARIATION IN COLOR OF DYED YARN EXPLAINED BY GRADE AND STAPLE; BY COLOR, S.A. NONLINT, AND UHM; AND BY RAW STOCK COLOR (R_d and +b) ONLY.

Based on test results for 1956 and 1959-60 studies of grade standards (above), and on samples in Annual Quality Studies, 1955-58 (below).

Manufacturing Waste, Figure 6. Manufacturing waste for the 1958 crop by classer's grade is approximately 1 1/2 percentage points lower for each grade than for the 1946 crop. In 1952 the amount of waste seems less in the higher grades, more in the lower grades than either 1946 and 1958.

On the other hand, the relationship between manufacturing waste and the laboratory measure of Shirley Analyzer nonlint content seems to show no significant change over the years.

Yarn Strength, Figure 7 (Grade Varying) and Figure 8 (Staple Varying). In early years, the differences in yarn strength between grades, holding staple constant, were very small (figure 7), but in 1958 the differences were large. The strength difference between Good Middling and Good Ordinary in 1946 was 1 1/2 pounds per skein; in 1958 the difference was 29 pounds per skein.

The relationship between color and strength shows practically the same trend, that is, little relationship in 1946, but a distinct relationship in 1958.

The relationships shown by grade and by color in figure 7 are misleading because they seem to show that the difference in yarn strength between grades has increased progressively from 1946 to 1958. A comparison of regression lines for intervening years shows that, with the exception of 1949 and 1950, the differences in yarn strength between grades have been increasing gradually since 1946. There is no significant difference between grades for 1949, 1950, and 1958, although the level of yarn strength was higher in 1958 than in 1949 or 1950.

When classer's staple, holding grade constant (figure 8), is studied as a variable in explaining yarn strength, in addition to the obvious fact that longer staples usually make stronger yarns, it appears that in 1958 yarns made from the same lengths were stronger than in earlier years. The Fibrograph UHM shows the same trends.

Yarn Appearance, Figure 9. The regression lines show very little difference in yarn appearance between grades. This supports the conclusion based on figure 3 that there never has been much relationship between appearance and grade. Appearance seems to be about one-fourth grade lower in 1958 than in 1946 for the same grade. Similarly, for the same ~~sample~~ Micronaire readings, appearance is lower in 1958 than in earlier years.

Color of Bleached Yarn, Figure 10. The Cotton Division did not begin finishing tests until 1955. Results for 1955-1958 show that yarns bleach whiter for higher than for lower grades, and that results for each year are essentially the same, with the exception that the 1958 crop seems to have bleached somewhat whiter than the other years, whether judged on a basis of classing or laboratory measures.

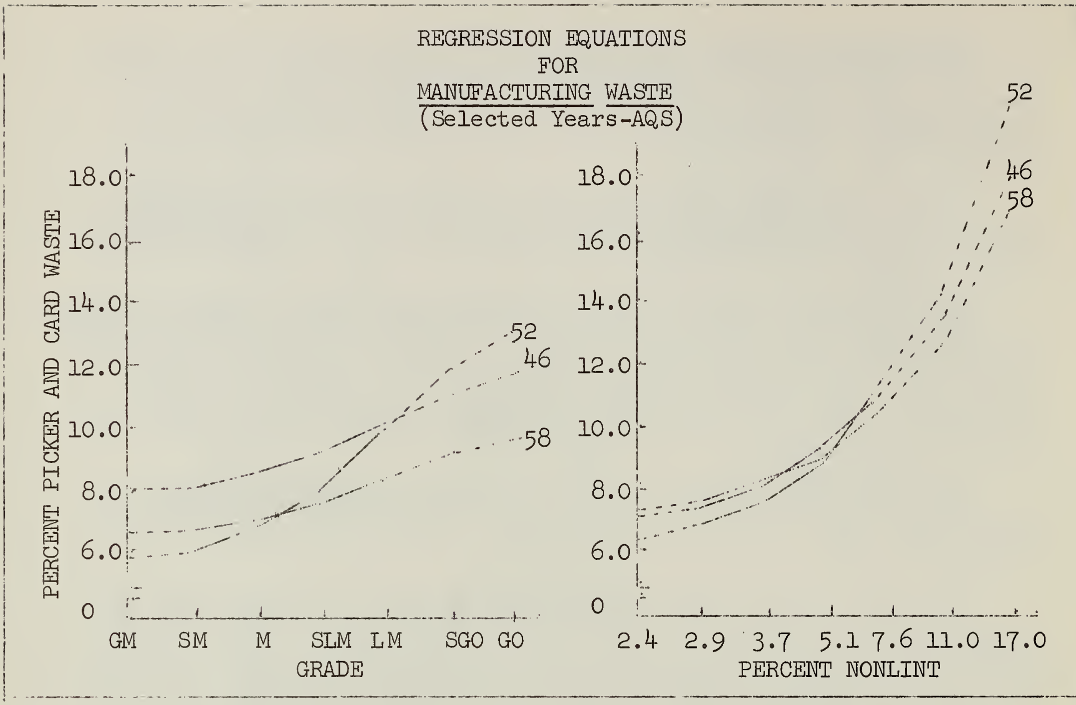


FIGURE 6.--REGRESSION EQUATIONS PLOTTED FOR MANUFACTURING WASTE USING GRADE AND STAPLE AS VARIABLES WITH STAPLE CONSTANT; COLOR, S.A. NONLINT, AND UHM AS VARIABLES WITH COLOR AND UHM CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1946, 1952, and 1958.

MANUFACTURING WASTE WITH GRADE AND STAPLE

1946 $X_7 = 29.20191 - .10175X_{88} - .30978X_{10}$

1952 $X_7 = 29.10714 - .20165X_{88} - .05631X_{10}$

1958 $X_7 = 21.44694 - .08196X_{88} - .18007X_{10}$

MANUFACTURING WASTE WITH COLOR, S.A. NONLINT, UHM

1946 $X_7 = 15.96982 - .41829X_{64} + .74219X_{248} - 6.45364X_{17}$

1952 $X_7 = 6.30098 - .01793X_{279} + .94931X_{248} - .72006X_{17}$

1958 $X_7 = 14.04754 - .04892X_{156} + .66155X_{248} - 4.50186X_{17}$

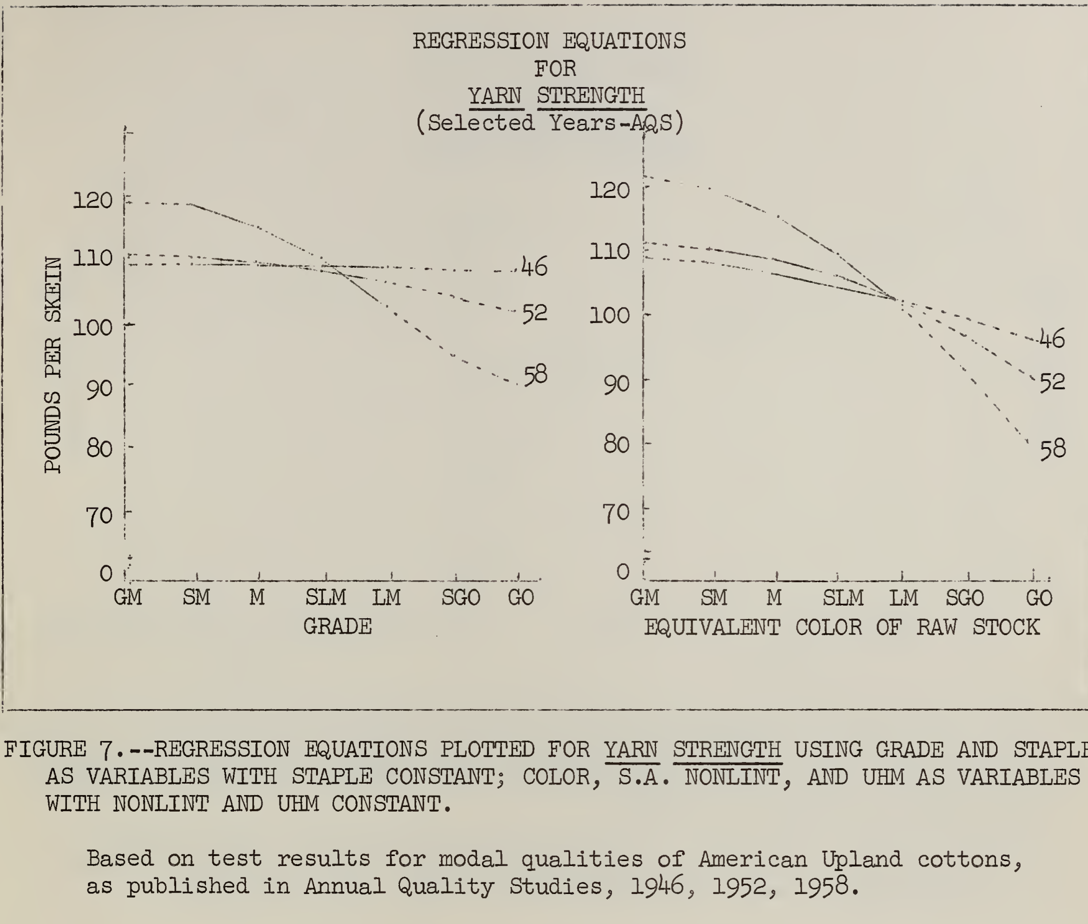


FIGURE 7.--REGRESSION EQUATIONS PLOTTED FOR YARN STRENGTH USING GRADE AND STAPLE AS VARIABLES WITH STAPLE CONSTANT; COLOR, S.A. NONLINT, AND UHM AS VARIABLES WITH NONLINT AND UHM CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1946, 1952, 1958.

YARN STRENGTH WITH GRADE AND STAPLE

1946 $X_8 = -29.63604 + .04566X_{88} + 4.07417X_{10}$

1952 $X_8 = -34.94359 + .22372X_{88} + 3.71286X_{10}$

1958 $X_8 = -67.38766 + .84009X_{88} + 2.99920X_{10}$

YARN STRENGTH WITH COLOR, NONLINT, UHM

1946 $X_8 = -73.41733 + 9.42623X_{64} + 92.28415X_{17} + 1.09675X_{248}$

1952 $X_8 = -39.69242 + 1.15695X_{279} + 58.78252X_{17} - .46169X_{248}$

1958 $X_8 = -82.10357 + 1.74287X_{156} + 63.98668X_{17} + .02680X_{248}$

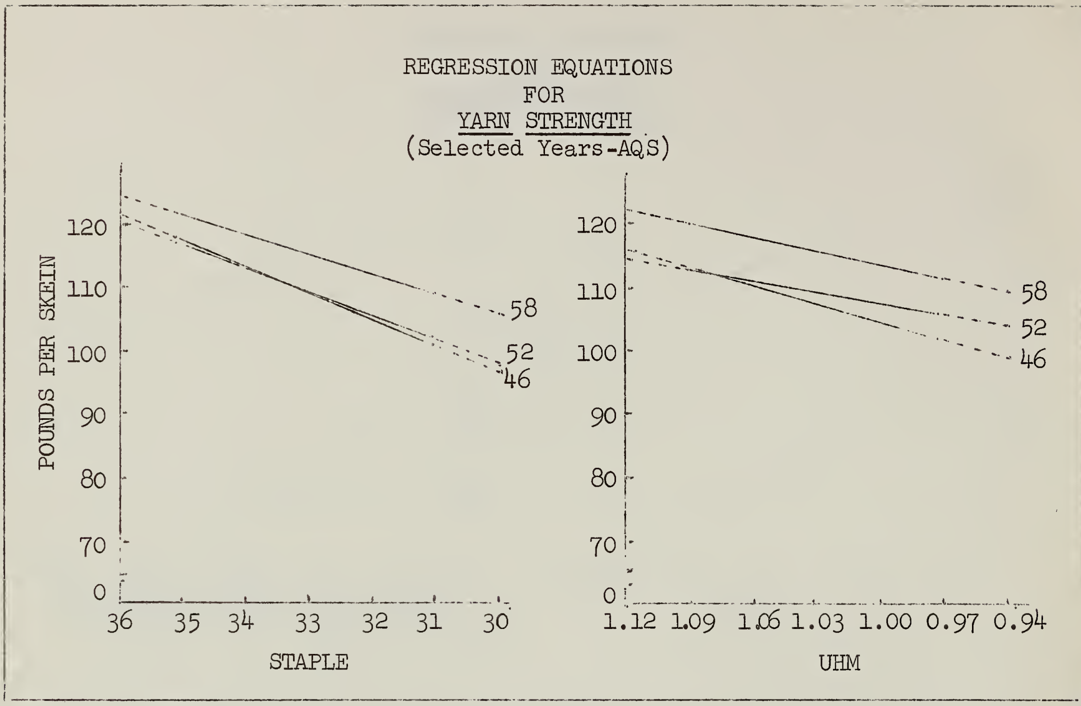


FIGURE 8.--REGRESSION EQUATIONS PLOTTED FOR YARN STRENGTH USING GRADE AND STAPLE AS VARIABLES WITH GRADE CONSTANT; COLOR, S.A. NONLINT, AND UHM AS VARIABLES WITH COLOR AND NONLINT CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1946, 1952, and 1958.

YARN STRENGTH WITH GRADE AND STAPLE

1946 $X_8 = -29.63604 + .04566 X_{88} + 4.07417 X_{10}$

1952 $X_8 = -34.94359 + .22372 X_{88} + 3.71286 X_{10}$

1958 $X_8 = -67.38766 + .84009 X_{88} + 2.99920 X_{10}$

YARN STRENGTH WITH COLOR, NONLINT, UHM

1946 $X_8 = -73.41733 + 9.42623 X_{64} + 92.28415 X_{17} + 1.09675 X_{248}$

1952 $X_8 = -39.69242 + 1.15695 X_{279} + 58.78252 X_{17} - .46169 X_{248}$

1958 $X_8 = -82.10357 + 1.74287 X_{156} + 63.98668 X_{17} + .02680 X_{248}$

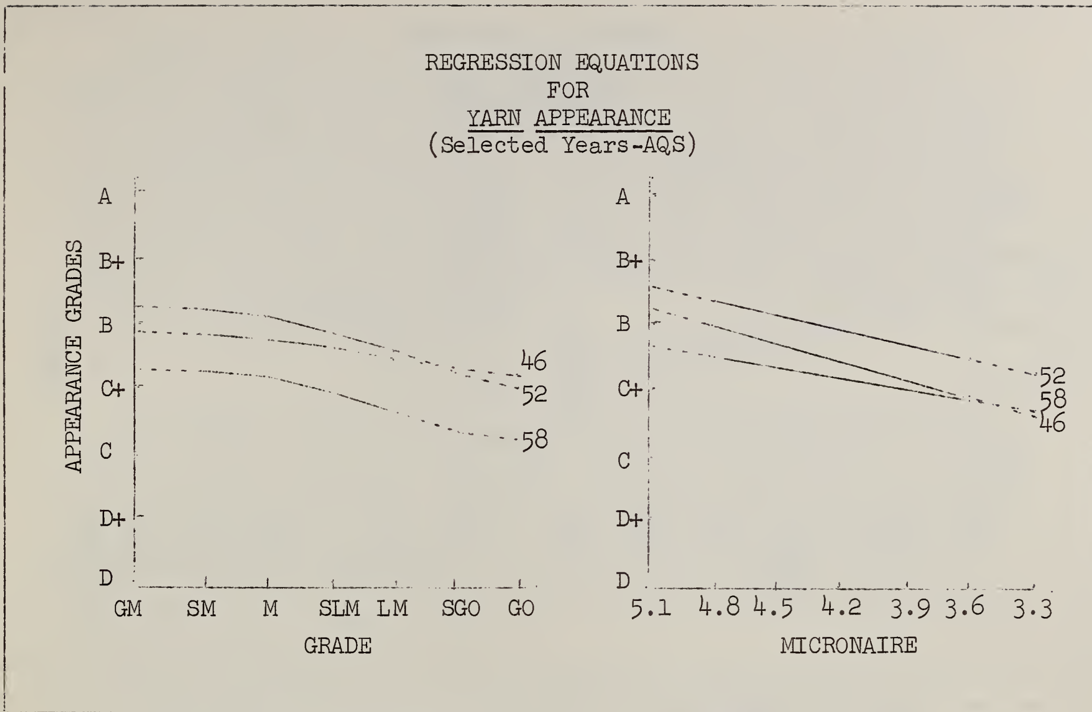


FIGURE 9.--REGRESSION EQUATIONS PLOTTED FOR YARN APPEARANCE USING GRADE AND STAPLE AS VARIABLES WITH STAPLE CONSTANT; GRADE AND STAPLE WITH MICRONAIRE AS VARIABLES WITH GRADE AND STAPLE CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1946, 1952, and 1958.

YARN APPEARANCE WITH GRADE AND STAPLE

1946 $X_{98} = 151.24303 + .17657X_{88} - 1.83069X_{10}$

1952 $X_{98} = 78.00076 + .33980X_{88} - .00860X_{10}$

1958 $X_{98} = 67.87730 + .32436X_{88} - .05986X_{10}$

YARN APPEARANCE WITH GRADE, STAPLE, MICRONAIRE

1946 $X_{98} = 50.96234 - .02150X_{88} + .53538X_{10} + 9.16570X_{4}$

1952 $X_{98} = 51.37384 + .26126X_{88} + .06525X_{10} + 7.14012X_{104}$

1958 $X_{98} = 49.78213 + .33204X_{88} - .11095X_{10} + 5.36083X_{104}$

REGRESSION EQUATIONS
FOR
BLEACHED YARN
(1955-1958 AQS)

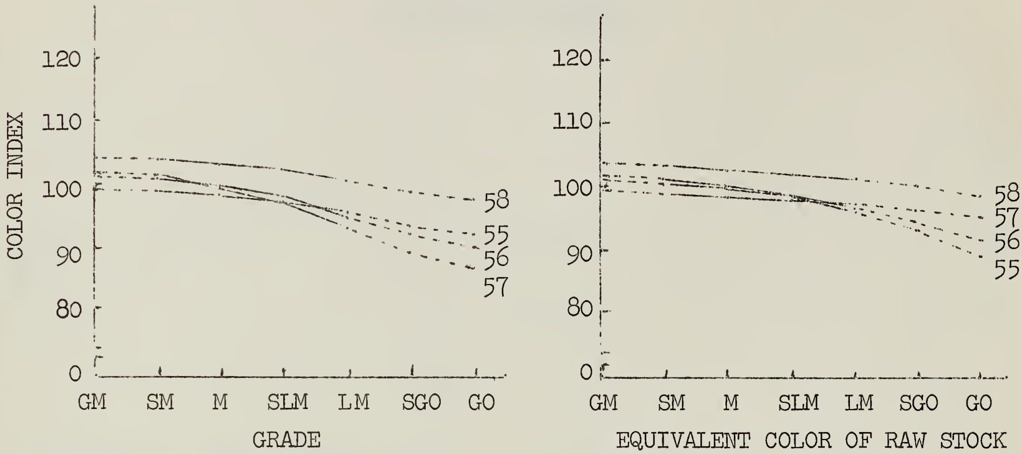


FIGURE 10.--REGRESSION EQUATIONS PLOTTED FOR BLEACHED YARN USING GRADE AND STAPLE AS VARIABLES WITH STAPLE CONSTANT; COLOR, S.A. NONLINT, AND UHM AS VARIABLES WITH UHM AND NONLINT CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1955 - 1958.

BLEACHED YARN WITH GRADE AND STAPLE

1955 $X_{252} = 53.06941 + .20126X_{88} + .77509X_{10}$

1956 $X_{252} = 57.67877 + .31097X_{88} + .33855X_{10}$

1957 $X_{252} = 40.89992 + .41648X_{88} + .52391X_{10}$

1958 $X_{252} = 77.24793 + .18909X_{88} + .21757X_{10}$

BLEACHED YARN WITH COLOR, S.A. NONLINT, UHM

1955 $X_{252} = 41.51789 + .64938X_{279} + 7.00072X_{17} + .08130X_{248}$

1956 $X_{252} = 59.28343 + .40994X_{156} + 10.78534X_{17} - .36402X_{248}$

1957 $X_{252} = 64.80116 + .19954X_{156} + 21.34265X_{17} - .92607X_{248}$

1958 $X_{252} = 80.45979 + .20625X_{156} + 7.91748X_{17} - .41762X_{248}$

Color of Dyed Yarn, Figure 11. The color differences between grades are larger for dyed than for bleached yarns, which indicates either that grade influences dyeing more than it does bleaching, or—what seems more likely—that the color differences in bleached yarns are so small that the precision of the test measurements is not adequate to pick them up consistently. It is clear from figure 11 that yarns made from higher grades dye a deeper color (higher index) than those of lower grades. The levels between years are fairly constant, except for 1956 for which results are somewhat lower, whether judged by classing or by laboratory measures.

COMPARATIVE COSTS OF TESTING

Instrument testing, when it can be done by precision methods and repeated within very close tolerances, has certain advantages over visual or manual testing whether that testing is performed by a classer or by laboratory personnel. However, the lack of precision for many of our present laboratory test methods must be faced and improved before instrumentation can possibly be expected to do more than supplement visual and manual testing. But if instrumentation were adequate in this regard, let us take a look at the costs involved in classification versus laboratory testing (table 2)

Table 2.--Estimate of costs involved for classification, for instrument testing by laboratory, and by volume testing

Classification		Instrument Tests				
			Laboratory testing		Volume testing	
Determination by:	Cost	Determination by:	Number of tests	Estimated cost	Number of tests	Estimated cost
Grade and staple	$0.25	Colorimeter	1	$0.25	1	$0.05
		Fibrograph	4	1.50	1	0.25
		Shirley Analyzer	1	2.00	1	1.00
Subtotal	0.25		6	3.75	3	1.30
		Micronaire	2	0.75	1	0.05
		Pressley	6	1.50	1	0.25
Total	$0.25		14	$6.00	5	$1.60

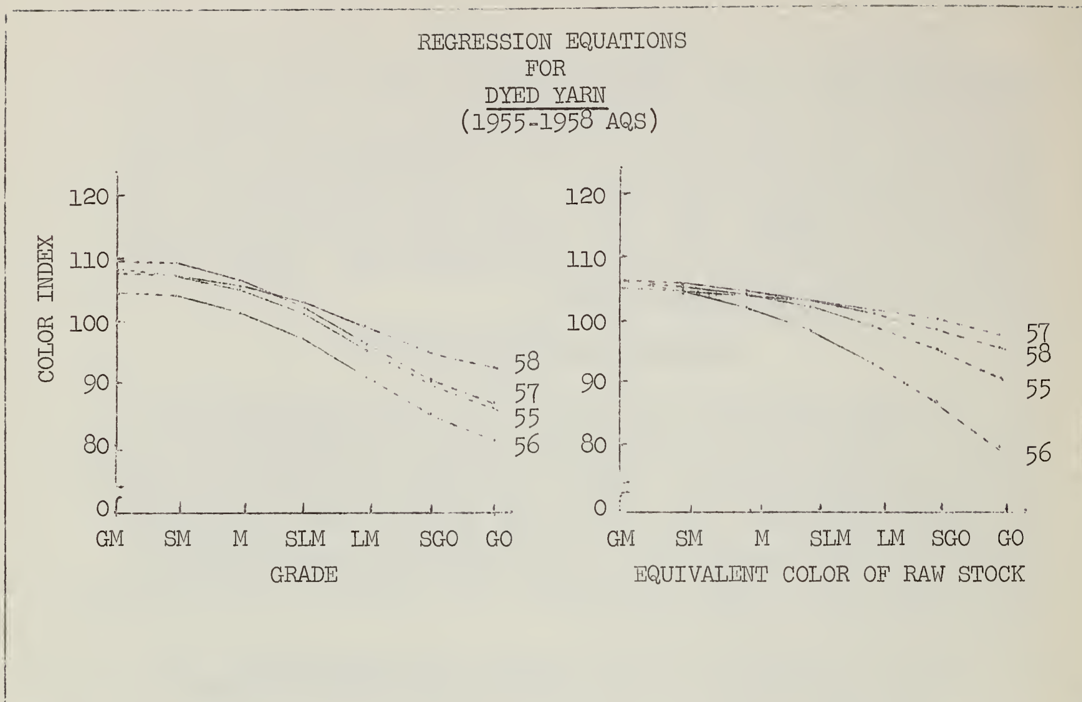


FIGURE 11.--REGRESSION EQUATIONS PLOTTED FOR DYED YARN USING GRADE AND STAPLE AS VARIABLES WITH STAPLE CONSTANT; COLOR, S.A. NONLINT, AND UHM AS VARIABLES WITH UHM AND NONLINT CONSTANT.

Based on test results for modal qualities of American Upland cottons, as published in Annual Quality Studies, 1955 - 1958.

DYED YARN WITH GRADE AND STAPLE

1955 $X_{253} = 37.51843 + .61181 X_{88} + .19255 X_{10}$

1956 $X_{253} = 45.07549 + .66491 X_{88} - .30711 X_{10}$

1957 $X_{253} = 7.96101 + .64945 X_{88} + 1.02085 X_{10}$

1958 $X_{253} = 41.65943 + .42304 X_{88} + .65460 X_{10}$

DYED YARN WITH COLOR, S.A. NONLINT, UHM

1955 $X_{253} = 47.38768 + .82186 X_{279} - 1.60735 X_{17} - 1.51065 X_{248}$

1956 $X_{253} = 19.81380 + 1.08796 X_{156} + .96475 X_{17} - .29707 X_{248}$

1957 $X_{253} = 56.21633 + .28446 X_{156} + 32.82492 X_{17} - 2.02232 X_{248}$

1958 $X_{253} = 52.06314 + .43726 X_{156} + 20.40168 X_{17} - .38948 X_{248}$

Classer's grade and staple costs 25 cents, similar laboratory measures cost $3.75 if a sufficient number of tests per sample are performed to obtain reliable results. By reducing the number of tests per sample and performing the tests more economically, these costs can be reduced to approximately $1.30 but the accuracy of instrument testing would be greatly reduced. The Micronaire and Pressley tests would cost an additional 30 cents for a small number of tests per sample. If the number of Fibrograph and Pressley tests are reduced to one per sample, the accuracy of testing would be greatly reduced. In fact, if the testing for color, nonlint content, and fineness are performed at speeds which would reduce the cost as outlined in table 2, accuracy would be sacrificed to a certain extent.

No doubt the cost of some of these laboratory tests can be reduced when performed on a production basis or when performed by use of new developments for testing. For example, Dr. Earl E. Berkley is in the process of developing a Fractionator which measures essentially the same thing as the Shirley Analyzer, but at a much faster rate. But until faster methods for length and strength determinations are developed, the laboratory cannot hope to match classing costs to give the same amount of information.

Regardless of the cost involved, laboratory tests are important and are included both in developing and maintaining standards for grade and staple, and as an aid in determining the accuracy and level of cotton classification. Bales are selected for use in the standards only when they meet both classing and laboratory specifications.

TESTS FOR FUTURE ANALYSIS

We do not know what relationships would be discovered if a spinning performance or ends-down test could have been added to the five quality measures used as a basis for the studies reported, but we hope that within the next year spinning performance tests will be included in our statistical studies as a sixth dependent variable. By incorporating in 1960 a spinning potential test into the regular testing program of the Cotton Division, we shall have available data on the 1960 crop results on which to make statistical studies of the relationship between various fiber properties and the spinning performance. Beginning with the 1959 crop we are including a measure for "short fibers" in our computer program. These and other relationship studies will be made available as they are completed.

SUMMARY AND CONCLUSIONS

One factor alone explains most of the variance for each of the following: manufacturing waste, yarn strength, yarn appearance, color of bleached yarn, and color of dyed yarn. When that factor is a part of the classer's "grade and staple," or of the laboratory's measures that are similar to "grade and staple," then the results are all approximately the same. When the explanation is related to a factor not included in standards for grade and staple, then additional tests are needed in order to provide a better prediction of the quality measure that is deemed important (figures 1 to 5).

For the full range of grades or staples in the standards bales, there is very little difference between the amount of variation explained by the classer and that explained by laboratory measures that are similar to grade and staple (table 3). In the Annual Quality Studies, with a considerably restricted range of grades and staples, the explained variation is lower than for the more complete range of the standards, yet the differences between the variation explained by the classer and by similar laboratory measures are relatively on the same level.

Regression lines illustrated by figures 6-11 indicate: (1) that waste is less for the same grades in 1958 than in 1946, but that over the years the relationship between waste and Shirley Analyzer nonlint has remained nearly constant; (2) that differences in yarn strength between grades have increased gradually since 1946 (with exceptions in 1949 and 1950), that this gradual trend of change is confirmed by the relationships shown between yarn strength and color, and that yarns made from the same lengths are stronger in 1958 than in earlier years, whether measured by classer or laboratory; (3) that appearance of yarn is slightly lower in 1958 than in earlier years for the same grades and same Micronaire readings; (4) that yarns bleach whiter for higher than for lower grades, and with one exception are on about the same level for all years, whether judged by classing or laboratory measures; (5) that the dyed yarn index shows a considerable relationship to grade, and to color, with only slightly different levels between years.

Based on comparative costs of testing, it seems clear that until more precise measurements can be made by laboratory instruments which are economically comparable to classification, the most practical approach is to use these tests in developing and maintaining standards, and as a supplement and aid to grade and staple classification. This is the use being made of laboratory tests by the Cotton Division in its standardization and classing program on an ever widening scale. In fact, much of the pioneering work in the development of fiber testing methods originated in the Department's cotton standardization laboratories, as far back as 1927 when the Cotton Division established its fiber testing and color laboratories because, even then, they realized clearly that grade and staple do not explain sufficiently well the total contribution of various fiber properties to spinning performance and product quality of cotton.

The information presented today, based on tests made over the past 13 years, contributes to our understanding of quality evaluation by making it clear that grade and staple still provide a good "first approximation" to cotton quality evaluation; although they do not cover, nor have they ever covered, several of the important fiber properties needed to predict more fully the spinning quality or use-value of cotton.

TABLE 3.--VARIATION FOR FIVE COTTON QUALITY MEASURES EXPLAINED BY CLASSIFICATION, BY EQUIVALENT LABORATORY TESTS, AND BY SUPPLEMENTAL LABORATORY TESTS.

Summary of averages based on test results for studies on standards bales, and on samples in Annual Quality Studies

Quality Measures	Percent Variance Explained By: Grade and Staple	Color Nonlint UHM	One Measure		Grade and Staple Plus Supplemental Measure	Color Nonlint UHM Plus Supplemental Measure
BASED ON STANDARDS BALES (FULL RANGE OF GRADES OR STAPLES)						
% Manufacturing Waste 1/	91	95	95	Nonlint		
Yarn Strength 2/	81	85	76	Fiber Strength	88	90
Yarn Appearance 1/	28	31	32	Micronaire	43	46
Bleached Yarn Color 1/	69	72	67	Raw Stock Color		
Dyed Yarn Color 1/	76	75	74	Raw Stock Color		
BASED ON ANNUAL QUALITY STUDIES (RESTRICTED RANGE OF GRADES AND STAPLES)						
% Manufacturing Waste	45	62	55	Nonlint		
Yarn Strength	45	52	52	Fiber Strength	62	65
Yarn Appearance	8	12	22	Micronaire	26	30
Bleached Yarn Color	25	24	18	Raw Stock Color		
Dyed Yarn Color	34	41	28	Raw Stock Color		

1/ Based on grade standards bales.
2/ Based on staple standards bales.

LITERATURE CITED

(1) United States Department of Agriculture
1955. Cotton Testing Service. Agri. Mktg. Serv. AMS No. 16

(2) Nickerson, D. and Newton, F. E.
1958. Grade and Color Indexes Developed for Evaluation Results of USDA Cotton Finishing Tests. Agri. Mktg. Serv. AMS-245

(3) Webb, R. W.
1957. Equations for Predicting Single-Strand Yarn Strength and Elongation Based on Measures of Raw-Cotton Quality. U. S. Dept. Agri., Agri. Mktg. Serv. Marketing Research Report No. 197, 40 pp.

(4) United States Department of Agriculture
1946. Fiber and Spinning Test Results for Some Upland Cottons Grown in Selected Standardized-Variety Areas, Crop of 1946, pp. 10-13. Prod. and Mktg. Admin.

(5) ______
1947. Fiber and Spinning Test Results for Some Pure Varieties Grown by Selected Cotton Improvement Groups, Crop of 1947, pp. 4-7. Prod. and Mktg. Admin.

(6) ______
1949. Summary of Fiber and Spinning Test Results for Cotton Varieties Grown by Selected Cotton Improvement Groups, Crop of 1948, pp. 6-19. Prod. and Mktg. Admin.

(7) ______
1950. Summary of Fiber and Spinning Test Results for Cotton Varieties Grown by Selected Cotton Improvement Groups, Crop of 1949, pp. 7-21. Prod. and Mktg. Admin.

(8) ______
1951. Summary of Fiber and Spinning Test Results for Cotton Varieties Grown by Selected Cotton Improvement Groups, Crop of 1950, pp. 8-22. Prod. and Mktg. Admin.

(9) ______
1952. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement groups, Crop of 1951, pp. 10-24. Prod. and Mktg. Admin.

(10) ______
1953. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1952, pp. 8-22. Prod. and Mktg. Admin.

(11) United States Department of Agriculture
1954. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1953, pp. 9-25. Agri. Mktg. Serv.

(12) ______ 1955. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1954, pp. 8-25. Agri. Mktg. Serv. AIB No. 137

(13) ______ 1956. Summary of Fiber and Spinning Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1955, pp. 9-27. Agri. Mktg. Serv. AIB No. 152

(14) ______ 1957. Summary of Fiber and Processing Test Results for Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1956, pp. 9-55. Agri. Mktg. Serv. AIB No. 170

(15) ______ 1958. Summary of Fiber and Processing Test Results on Some Varieties of Cotton Grown by Selected Cotton Improvement Groups, Crop of 1957, pp. 9-59. Agri. Mktg. Serv. AIB No. 186

(16) ______ 1959. Annual Cotton Quality Survey — Summary of Results of Fiber and Processing Tests from Selected Market Areas. Crop of 1958, pp. 12-62. Agri. Mktg. Serv. AIB No. 206

(17) ______ 1960. Annual Cotton Quality Survey — Summary of Results of Fiber and Processing Tests from Selected Market Areas, Crop of 1959, pp. 10-112. Agri. Mktg. Serv. AIB No. 227

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Cotton Division

COLOR CODE
FOR RELATING COLOR MEASUREMENTS OF RAW COTTON TO COLOR IN GRADE STANDARDS

* * * * *
* * *
*

AMS--411 Washington 25, D. C. October 1960

COLOR CODE FOR RELATING COLOR MEASUREMENTS [1/] OF RAW COTTON TO COLOR IN GRADE STANDARDS

In reports of Cotton Fiber and Processing Test Results for Crop of 1960 the color of raw cotton is reported in a single code number that is converted from R_d and b instrument values reported in previous years as measures of reflectance and yellowness. As stated in the first of the reports published this year (August 8, 1960), this code provides a closer identification of color measurements with the color of official grade standards than do the R_d and b color measurements used in previous years.

The code consists of three numbers: The first relates to grade (3, Good Middling, 4, Strict Middling, etc.); the second number relates to placement in the upper half of the grade, for example, 30 for the top half of GM, 35 for the lower half of GM, 40 for the top of SM, etc.; the third number, beginning with 1 to represent the whitest side of the grade, increases through the White and Spotted grades to 9 for the color of Yellow Stained grades. The number 401 thus designates SM on the high side of the grade, and very white--a color typical of SM cottons from California. The code number 403 designates SM on the high side of the grade for reflectance but more yellow in color, typical of SM cottons from the Texas and Oklahoma area. The number 457 indicates SM on the low side, with 7 degrees of yellow color, enough yellow to put the sample into a Tinged grade.

Figures 1 and 2 illustrate this code and its use in relation to color measurements made on the Nickerson-Hunter Cotton Colorimeters in terms of both the R_d and b scales, and the grade standards for American Upland cottons.

1/ In relation to color studies of cotton, a series of diagrams and tables prepared for use at the 1959 Universal Grade Standards Conference contain information useful to anyone interested in this subject. These and a 1960 report are available from the Cotton Division, AMS, as follows:

GRADE STANDARDS STUDIES:
- No. 1. Color Measurements of Grade Standards, 1952-1959.
- No. 2. Summary of Color Measurements from Surveys of Cotton Classed in 8 Crop Years, 1951 to 1958.
- No. 3. Trash and Color.
- No. 4. Color Change in Storage.

COTTON COLORIMETER, an aid in extending knowledge of cotton quality. Presented at ACMI Open House, Clemson, S. C., May 4, 1960.

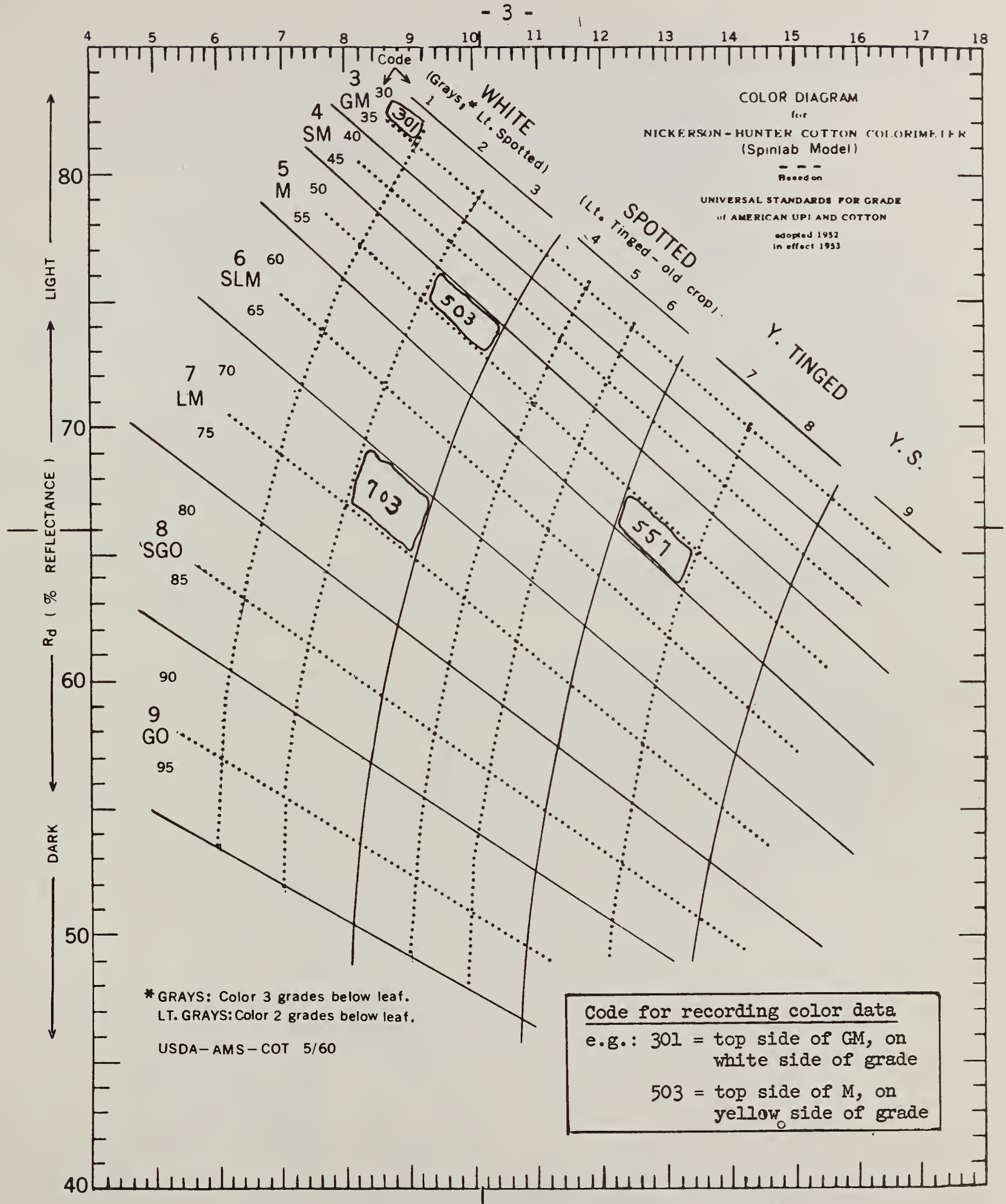


FIG. 1.--CODE FOR RELATING COLOR MEASUREMENTS OF RAW COTOON TO COLOR IN GRADE STANDARDS. Color measurements may be reported in terms of R_d and b, in terms of equivalent grade, or in terms of the code illustrated above, according to the precision that may be required.

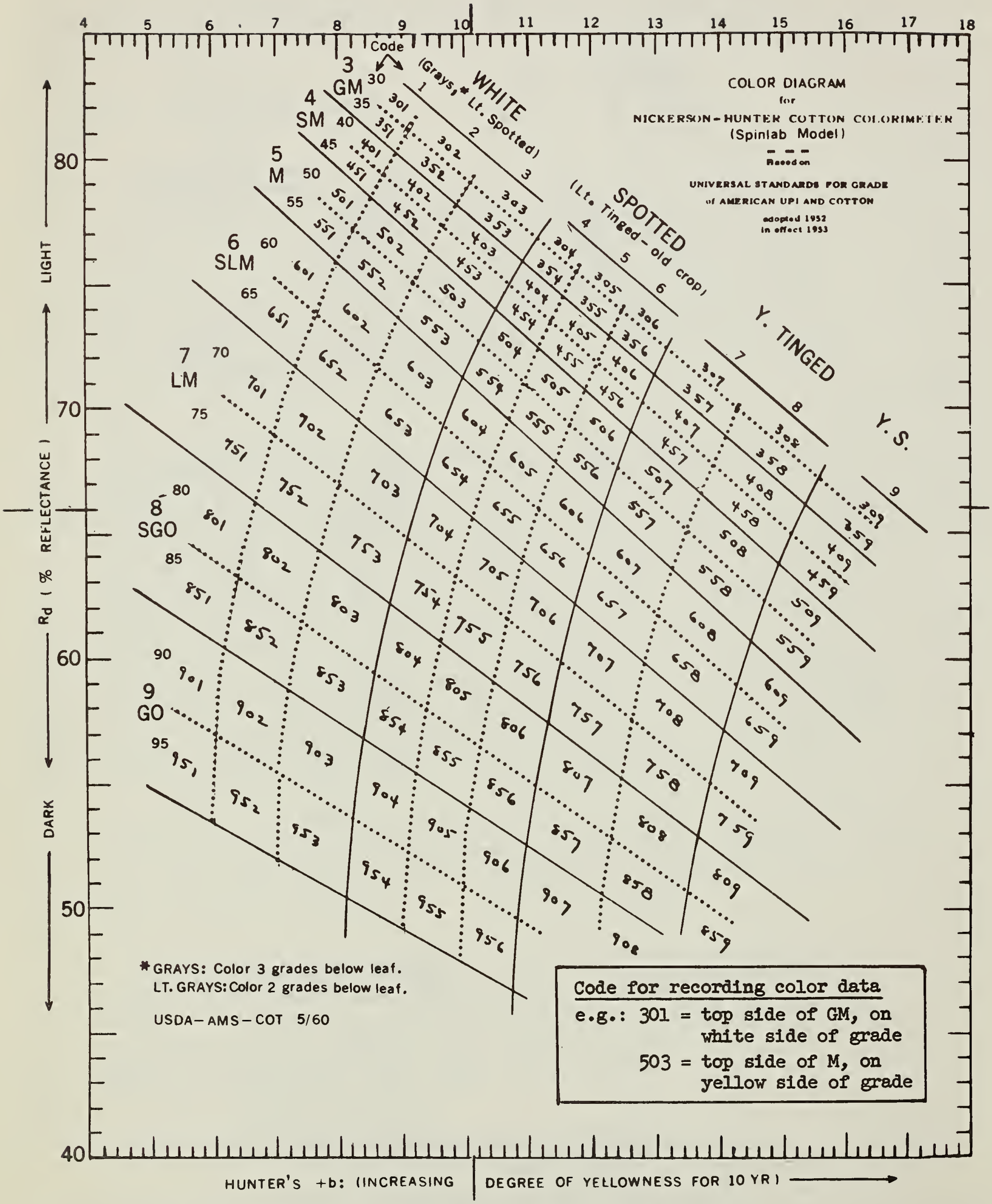


FIG. 2.--CODE FOR RECORDING COLOR MEASUREMENTS OF RAW COTTON SAMPLES.
Application of code shown in detail for entire color range of American Upland cottons.

* - *

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington 25, D. C.

WHERE WE ARE IN MEASURING COLOR AND TRASH

A report by Harvin R. Smith, Cotton Marketing Specialist, Standardization Section, Standards and Testing Branch, Cotton Division, before the 1961 Cotton Research Clinic, Memphis, Tennessee — May 16, 1961

The Cotton Division, AMS, has been interested in the accurate and precise measurement of color and trash for many years. Color and trash, along with preparation, form the basic components of cotton grade. In the physical preparation of cotton grade standards, the accurate measurement of these factors is vital to our success, for cotton is a variable product. Not only does it vary in color and trash from bale to bale, it even changes color in storage in different amounts depending upon the conditions under which it is stored. With time and use, cotton standards also change color or get dusty. Every year it is necessary to reproduce several thousand boxes of cotton standards. They must uniformly represent the color, trash, and preparation of the standards as they were at the time of adoption.

If we are to discuss "where we are," first we need to find some points of reference, some milestones, or some well defined standards by which we can measure the progress that has been made.

With the measurement of color our present position is quite clear. We have passed many milestones since 1927 when Dorothy Nickerson first tackled the problem of color measurement of cotton. At that time color itself lacked definition and organization. Today we have international agreement. The terms and units under which color may be described and measured are now well standardized. This has been translated into instrument circuity with accuracy and precision. We had help. It was the great demand for instruments to measure color outside of the cotton industry that made it possible. The paint, printing ink, dye, plastics, ceramics and food industries, to mention but a few, were all concerned and interested in the measurement of color. As a result of this widespread interest, and of our own needs, we now have instruments that will measure cotton color automatically, rapidly, accurately, and with precision. The Department of Agriculture, which had one visual disk colorimeter in 1929, one electronic instrument in 1950, six by 1953, now has 26 cotton colorimeters in its various laboratories and classing rooms.[1] They are used in our standardization and survey programs, and as an aid to the classer in keeping his level of grading in line with the standards. Cotton colorimeters are also used to an increasing degree by cotton manufacturing and marketing firms throughout the world. Our records show that we have calibrated 90 sets of scales and tiles for use on cotton colorimeters, so we assume that there are about that many in operation. Use of these tiles in keeping instruments in careful calibration insures that colorimeter measurements can be related accurately to the level of the cotton grade standards.

---

1 Subscript numbers refer to lantern slide illustrations.

Precision and accuracy are the basic requirements of any instrument. Automation, speed, and convenience are secondary considerations. Once we get precision and accuracy, then speed, automation, economy, and convenience can be applied, and with the colorimeter, many such improvements along these lines already are made, and are still being made.

When we speak of precision in measuring cotton color, we speak in terms which seem fantastically small when compared to the precision of most other fiber testing instruments used today. This is not without reason, for the human eye, while not very good at determining or remembering absolute levels of color, has a remarkable ability to distinguish very small differences in color. The Cotton Colorimeter must do as well or better than the eye in both of these fields in order to produce useful information. The precision of the Nickerson-Hunter Cotton Colorimeter is shown in Table 1, and may be better illustrated on a color diagram.[2] The data show that the range of measurements for repeated readings on the same samples is very small, both in absolute terms, and in terms relative to the size of color differences between grades. As for accuracy, this instrument is carefully calibrated in terms of color scales that are standardized and well accepted in the field of colorimetry. These terms can be converted to, or from, other standard color units just as we can convert from inches into centimeters.

I should like to call your particular attention to the color diagram itself. It is this diagram that makes the instrument a cotton colorimeter, and thus distinguishes it from other color measuring instruments. This is accomplished by transforming the measured color of a sample into terms of equivalent cotton grades. Thus, the results may be easily understood by those in the cotton industry. This diagram is based on the average color readings of the cotton standards which have been in effect since 1953.

For our own use, except for reports or statistical studies, the R_d and +b scale readings are seldom recorded. Instead, we either record the position of the readings directly on diagrams such as you see here, in terms of equivalent cotton grades, or we read the position in terms of a grade-color code.1/ This code, we believe, enables a cotton man to relate his knowledge of cotton to the colorimeter measurements, and also allows him to distinguish and designate several color differences within each grade.

The colorimeter measures the average of whatever surface is presented to it. It still requires a classer, or an operator thoroughly familiar with the product being measured, to interpret the results correctly. The measurement is affected by spots, such as the yellow spots in the Spotted Grades, and by trash particles. For example, a sample reading in the range of the Spotted Grades may actually have a light tinged appearance, rather than a spotted appearance.

The diagram usually used on the Cotton Colorimeter refers to grades of Upland Cottons, but in our laboratories we also use diagrams based on standards for grades of American Egyptian cotton[3] and cotton linters.[4] In fact, this

---

1/ United States Department of Agriculture, "Color Code for Relating Color Measurements of Raw Cotton to Color in Grade Standards", AMS-411, October 1960.

Table 1.--Repeatability of measurements on the Nickerson-Hunter Cotton Colorimeter (Spinlab Model 191) for samples in different conditions as demonstrated by relative size of standard deviations around the means of R_d and b readings in the color range of the several grades

Color range of grades	Papers and enamels 1/		Same samples, 2/ repeat readings		Different samples, 3/ same bales		Different bales 4/	
	% R_d	+b	% R_d	+b	% R_d	+b	% R_d	+b
	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.
GM	.08	.04	.12	.06	.46	.09		
SM			.10	.06	.42	.15	1.5	.46
M			.13	.05	.30	.12	1.5	.42
SLM	.09	.05	.08	.06	1.0	.18	1.7	.52
LM	.00	.05	.11	.07	1.3	.19	2.2	.50
SGO			.08	.07	1.1	.16		
GO	.02	.06	.13	.07	1.2	.16		
	.07	.07						
	.00	.05						
SM Sp.	.07	.00	.09	.06	.36	.14	1.7	.34
M Sp.	.05	.00	.09	.07	.61	.26	1.7	.66
SLM Sp.			.14	.07	.72	.26	1.5	.65
LM Sp.	.09	.02	.08	.06	.78	.20	2.4	.28
SM Tg.	.08	.06	.09	.07	.81	.40		
M Tg.			.11	.06	.62	.28		
SLM Tg.			.11	.08	1.6	.64		
LM Tg.	.09	.07			.78	.27		
	.03	.06						

1/ Twenty-five independent measurements on each of several papers and enamel plaques used to test colorimetric accuracy of instrument.

2/ Twenty-five independent readings made over a period of several weeks on six cotton samples of each grade.

3/ One measurement on each of 12 cotton samples from the same bales.

4/ The samples in this series were taken at random from the 1959 Annual Quality Study. Up to 30 different bales are represented in each grade. (The spotted bales were Light Spotted.)

instrument can be adapted to measure the color of anything that falls within the range of color for which it is designed, and which can be prepared in a sample that is suitable for measurement.

Color measurements of cotton are used for many purposes, among them the following:

1. To maintain uniformity of standards.
2. To measure relationships between the color, leaf, and preparation factors in grade standards and those of cottons in current crops.
3. To aid the classer in maintaining a constant level of grade classification.
4. To establish facts relating to color change and its causes.
    a. Change caused by exposure in the field.
    b. Change caused by conditions of storage.
5. To establish facts concerning the effects of color and of factors related to it in processing or end use.
    a. Blending of mixes for more uniformity in processing or in product.
    b. Relationships between raw stock color and color of yarns or fabrics after bleaching and dyeing.

For one example, let us refer to studies of cotton storage. We have recently completed a test covering storage of grades under controlled conditions of temperature and humidity. For example, in three years' time there was little change in color for storage at 50°F. and 50% relative humidity,[5] but considerable change at 100°F.[6] A color picture showing the extent of these differences is shown on this next slide.[7]

In fact, on the basis of these studies we have been able to establish the pattern of color change with time, holding storage conditions constant,[8] and likewise to establish the pattern of color change for varying conditions of storage, with time held constant.[9]

With the possible exception of fiber length, the color of the cotton fiber provides more useful information to the experienced cotton man about the value, or utility, of cotton than any other single fiber measurement. It is why so much attention has been paid to its measurement, and why color is a basic and important component of cotton grade.

This is "where we are" in measuring the color of cotton; we have come a long way in providing for its precise and accurate measurement.

We have not traveled so far in respect to trash measurements. "Where we are" is not so clear. The first estimate of trash content is by the human eye. The trained eye still provides one of the best measures we have, certainly the most economical and the most widely used.

Another, and very logical, way to measure trash content is to separate the trash physically from the lint and weigh it, rather than to judge its appearance as the classer does. This separation is difficult because lint and trash tend to cling together. The Shirley Analyzer is the best device we have at the

present time for making a physical separation of lint and trash with a satisfactory degree of precision.[10] It separates about 1 to 2 percent trash, or nonlint content, from the very high grades to as much as 18 or 20 percent for the lowest grades, with repeat measurements varying as much as one percent. It is slow, and therefore expensive, to operate. Four or five samples per hour is a high rate of production.

We have, then, in routine use today two means of measuring trash: first, the classer's judgment, based on the appearance of the sample, and second, the Shirley Analyzer, which makes a physical separation of the lint and trash. The classer is less precise, but very economical, and his appraisal is widely used in marketing cotton. The Shirley Analyzer is more precise and accurate, but it is very slow, costly, and generally suitable only for laboratory use. A better measure is obviously needed.

In standardization work we require a better and faster measure. In duplicating standards we require an instrument that will scan the surface of cotton, much as the classer does. In other words, it must evaluate the appearance of a sample, and do it to a finer and more precise degree than the classer if it is to be used in preparing standards. For some studies less precision can be tolerated, but for measurements of individual samples any useful instrument must do a better job than the trained eye can do. As reported at the Research Clinic last year, we are using the Outlook Trashmeter,[11] a scanning device that has proven very useful in studies where we can make several measurements on a sample, or a bale, or where we can average measurements on several samples, as in making crop surveys.[2/] The method is fast -- only three or four seconds per sample, and very sensitive, but to measure individual samples on the basis of a single reading, in order to equal what a classer can do, greater precision is required. We expect to have a new and more precise model of this type in the near future.

The recently developed ACCO Fractionator[12] is another trash measurement device which physically separates trash from the lint, as does the Shirley Analyzer. An improved model of this instrument, now being evaluated by ACCO and by the Cotton Division, is designed to use a smaller sample than the Shirley Analyzer, with a processing time of only one minute per sample. Weighing the sample adds to the total time required to complete the test, but nevertheless, this is still considerably faster than the Shirley Analyzer. Preliminary results from our evaluation of the ACCO Fractionator indicate that some precision has been sacrificed in using the small sample size (10 grams as compared to 100 grams required by the Shirley Analyzer). Also, we do not get as complete a separation of the lint and trash as we would like; especially with low grade cottons. We are still experimenting, however, and the use of different procedures or processing times might improve the results.

The question now is what are we going to use as a basis for comparing the various trash measurements in order to evaluate them? What we are trying to predict is manufacturing waste, but this consists of more than just trash alone. Manufacturing waste is itself very difficult to measure with any degree of precision. In our own spinning laboratories where all of the

---

2/ Harvin R. Smith, "A New Cotton Trashmeter" paper presented at 1960 Cotton Research Clinic, Ashville, N. C., May 31, 1960.

settings, speeds, and operating procedures are carefully controlled, we still find differences of as much as two percentage points in picker and card waste on repeated measurements from the same bales. However, we can, and do use this test to make comparisons whenever relatively large numbers of samples are involved, for example, our Annual Quality Surveys.

In the 1960 Annual Quality Survey approximately 685 spinning lots were tested. The results of comparisons of picker and card waste with each of the trash measurements we were able to make on these cottons, are shown by the correlations reported in table 2.[13]

Table 2.--TRASH MEASUREMENT CORRELATIONS (r)
Annual Quality Survey - Crop of 1960

	Classer's Grade	Shirley Analyzer	Trashmeter		ACCO Fractionator
			Area	Count	
Picker & card	-.69	.70	.52	.54	.47
Classer's grade	—	-.70	-.70	-.73	-.55
Shirley Analyzer	-.70	—	.65	.58	.59
Trashmeter Area	-.70	.65	—	.97	.49
" Count	-.73	.58	.97	—	.50
ACCO Fractionator	-.55	.59	.49	.50	—

The table shows that the Shirley Analyzer and classer's grade are better at predicting picker and card waste than measurements on the other two instruments.

When we assume the Shirley Analyzer as a reference for comparison, classer's grade correlates best, with the Trashmeter and ACCO Fractionator next. But, if classer's grade is used as the reference for comparison, as is sometimes useful in survey and standardization studies, the table indicates that the Trashmeter and Shirley Analyzer show an equally high relationship.

None of these correlations are really very high. This is caused by the restricted range of grades in the survey, the inherent variation in the samples, and the lack of precision in the tests themselves. When using a full range of grades, the correlation levels are much higher - well above 0.90 for the Shirley Analyzer with classer's grade, and presumably as much higher for the other methods as well.

This is "where we are" in measuring trash. Our progress has been relatively slow, and we still have quite a long way to go.

Our cotton grade surveys provide an example of the use and importance of combined color and trash measurements. These are made each year on typical samples of each grade classed in the United States cotton crop. By measurements made on these samples we maintain a record of color and trash from year to year. This information is useful in evaluating changes in the crop, and in discovering the need for any adjustments that may be required in the cotton grade standards to keep them applicable to current crops. Such information is a necessary basis for any recommendations that may be made for improvement in standards.

While these surveys have shown no significant change in the color of recent crops, they do show that a very considerable change has occurred in the past few years in the amount and kind of leaf associated with a given color. The colorimeter, along with the Shirley Analyzer and Trashmeter, helps us to understand the degree of this change.

As reported by Nickerson at the A.C.M.I. Open House last year, trash levels have declined sharply since 1953, even in bales bought for use in the grade standards.3/ In recent crops the trash content of cotton grades measured by the Shirley Analyzer has been falling as much as one full grade below that in the bales used in the 1953 and previous standards.[14] This decrease in amount of leaf is so universal that even when bales are especially searched out to match the standards, few can be found with sufficient leaf. As a matter of information, the 1953 standards which we are now using contain the same amount of leaf as those dating back as far as 1936. There has been no intentional change in the amount of leaf in the standards during all these years.

What has color to do with this? Color measurements confirm and support the trends shown in trash levels. If you examine the color of the bales before and after cleaning on the Shirley Analyzer,[15] it is clear that in early years there was a regular pattern of color improvement after cleaning that amounted to a difference on the color diagram of at least one grade. A series of such diagrams made over the past years show progressively less color improvement with cleaning, until in 1958[16] practically no color improvment is shown in the higher grades, and far less improvement in the lower grades, than was shown in earlier years. This information does not tell anything about fiber damage, but it does indicate that the color of cleaned lint from samples with less trash than in former years, is lower today than it would have been if the sample had a trash content in proportion to the color and leaf required by the grade standards. In other words, the combination of color, leaf, and preparation in the grade standards does not represent the combination of color, leaf, and preparation that is occurring in most cottons of recent crops. It is obvious that classing today's cotton against such standards is difficult, because trash and color must be averaged to obtain a grade classification. In future, if the practice continues of removing more trash at the gin than in former years, it will become necessary either to describe cotton in terms of separate grade factors (call the color and leaf grade separately), or to recommend a change in standards to fit more closely the color and leaf combinations as they are ginned in today's crops.

3/ Dorothy Nickerson, "Cotton Colorimeter - An Aid in Extending Knowledge of Cotton Quality". Paper presented at A.C.M.I. Open House, Clemson, S. C., May 1960.

This, then, is "where we are" in measuring color and trash today. We have come a long way in measuring color. The results are useful and the measurements are rapid, precise and accurate. Improvements in automation, convenience, and simplicity are still being made and we hope efforts will continue in this field. With trash, we have not gone so far. There are still many basic problems to be solved regarding trash measurements, but we hope that with continued efforts we will soon have a method that will fill the need more adequately than today.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington 25, D. C.

RECENT TRENDS IN TRASH CONTENT OF RAW COTTON CREATE A PROBLEM IN GRADE STANDARDS

By Dorothy Nickerson, Head, Standardization Section, Standards and Testing Branch, Cotton Division 1/

In judging cotton quality, a visual examination of samples by a trained cotton classer has for many years been the chief method of judging the amount and kind of trash to be expected in a bale. Trash content is one of three factors—color, leaf-and-trash, and preparation—that he takes into consideration in judging grade. And grade, in turn, is but one of several judgments he makes in assessing the quality of a bale as a basis for purchase.

Good ginning practices can maintain good preparation and can remove much leaf and trash, but can do nothing to improve lint color once it is lost. Lint color is at its peak when well matured bolls open in good weather, and any change from this peak color, whether by premature opening by frost, freeze, or heat, by insect damage, or by exposure to weather after opening, will cause a deterioration in color, and consequently in grade.

For years grade standards have aided a cotton man to make consistent appraisals for color, trash content, and preparation. Until recently, the relation of these factors in most cottons the classer looked at, was about the same as it was in the standards. But this is no longer true, for while the trash content of the standards remains unchanged, more trash is now being removed than in earlier years. This means that the relation of color, trash, and preparation in cottons of current crops is no longer the same as it was only a decade ago before the requirements of mechanical harvesting led to an increasing use of lint cleaning equipment that has jumped from 28 gins in 1948 to about 400 in 1950, 3,500 in 1957, and over 5,000 by 1961, which is 90 percent of the 5,619 gins reported in the United States.

The separate factors are each as important today in indicating cotton quality as they were yesterday, but their relation, as they must be fitted into a single judgment of "grade," makes the grades of yesterday and of today seem different. It is as if we were grading boxes in terms of cubic content: a box with a capacity of 216 cubic inches could be packed with the same amount of loose powder regardless of dimensions, but if 12-inch merchandise is to be packed into this box, its separate dimensions must be specified to allow it. So with cotton. Combinations of color, trash, and preparation in a given grade have remained reasonably consistent for so long that one is tempted to forget that each factor provides for a separate quality element. More will

---

1/ Based on a report to the 1962 National Cotton Council's Cotton Research Clinic, Pinehurst, North Carolina, January 11, 1962.

be said later about the relationships of these separate factors, but let us first review the history of grade standards, since it is against these standards that the separate factors are measured.

The first cotton standards approved by the Department of Agriculture were for nine grades of white cottons developed in 1909 by a committee that consisted of "nine men, prominent in various branches of the cotton trade," with three experienced classers from the New York, New Orleans, and Dallas markets. These were wholly voluntary standards and their use never became widespread. But in 1914, under authority of the Cotton Futures Act new grades, prepared on the basis of these and of the Liverpool-upland standards, were adopted as "official cotton standards of the United States." 2/ Only the futures exchanges were obliged to use these standards, but all important spot exchanges adopted them voluntarily. In 1916 standards for yellow tinged, yellow stained, and blue stained grades were added to the white grades.

These standards remained in effect without change until July 1922, effective 1923, when certain changes were made—a few in the white grades, the yellow tinges made lighter in color, and descriptive standards adopted for colors between those for which practical forms were available. An averaging rule for factors embracing more than one grade was made a part of the official cotton standards. It now provides, 3/ among other things, "That in no event shall the grade assigned to any cotton or sample be more than one grade higher than the grade classification of the color or leaf contained therein."

Passage of the Cotton Standards Act in 1923 made use of these standards mandatory, for in connection with transactions or shipments in commerce it became unlawful to use any grade name or designation not used in these standards, excepting only transactions based on actual samples or private types. In 1924, after discussion and conferences with representatives of the American trade and European exchanges, these United States official grade standards, by formal agreement with European exchanges, became known also as Universal Standards for American upland cotton. All copies were to be prepared by the Department of Agriculture and, under a supplemental agreement, provision was made for holding periodic conferences for the sole purpose of examination and approval of sets of copies of the original Universal standards for use in the United States and by member associations. The first conference under the supplemental agreement was held in Washington, March 1925, and conferences were held biennially through 1933.

In 1935, effective 1936, a general revision was made, chiefly on account of color. In 1939 there was a conference. Then, because of World War II, none was held until 1946 when again the standards had to be changed because

---

2/ An interesting report regarding these standards, the development of specially lighted rooms for preparing copies, and of other safeguards for their maintenance, is contained in United States Department of Agriculture Service and Regulatory Announcement No. 6, 1916.

3/ See Federal Register, June 25, 1959, Sec. 28.480.

of color change that occurred in the seven year interval between conferences. The standards adopted in 1946 were approved by all segments of the trade except the American manufacturers who objected that by comparison to copies of the old standards they were whiter, less desirable, and lower value.

The next conference was held in 1950. At that time physical standards were requested for spotted and gray cottons. For this reason, and because the manufacturers reiterated their position that the standards had been lowered in 1946, the Department agreed to make a new survey of the crop. By that time the development of a rapid automatic cotton colorimeter made it possible to measure not only every bale but every sample in both the survey and standards. No evidence was found that standards had been lowered in 1946, but there was now so much information available as a result of the survey, both by color and trash measurements, that standards were revised in 1952, effective 1953, to "reflect the characteristics of recent cotton crops, insofar as color, leaf, and preparation are concerned." It is these standards, 4/ plus a Good Middling adopted in 1954, and the addition of Spotted grades, and a redefinition of certain descriptive grades, that are in effect today.

In all of these years a consistent effort has been made to maintain the standards on the level they were when originally established. The principal reason for revisions in 1933, 1946, and 1952 was the change that had taken place in color of the standards. Between conferences the cotton yellowed enough so that as new boxes were made to match the old, a gradual color drift took place that sooner or later made it impossible to find cottons in any new crop that would match the color of cottons in the standards boxes. This was particularly true of grades above Middling, for bales had to be searched out and purchased from stocks of old cottons. Until the revision of 1952, only a partial adjustment was made for this yellowing, for the visual impact of the color in old boxes of standards was an influence on cotton men that was hard to overcome until after development of the automatic cotton colorimeter finally convinced even the most skeptical that accurate and precise color measurements were possible. These measurements showed that the primary cause of the periodic need to change standards was that the cottons used in the standards boxes changed 5/ with time. While some of the change was caused by a change in varieties, a few naturally creamy varieties being replaced by white ones, this was not the major cause of the need for a color change in standards, as some cotton men explained it in wishfully hoping for a return of the creamier cottons they preferred. (Not until the 1952 standards was an irrigated bale of cotton, with its "extra white" color, allowed representation in the white grades.)

But in all the years when periodic revisions had to be made in standards on account of color, no intentional change was made in either the level or kind of leaf. In preparing boxes for review at each conference, the leaf

---

4/ See D. Nickerson, COLOR MEASUREMENTS OF COTTON....Including a Discussion of Recent Work on Standards for Grade, 38 pp., March 1953, and COLOR OF GRADE STANDARDS, 1909-54, 15 pp., April 1954, obtainable from Cotton Division, A.M.S., U. S. Dept. of Agriculture, Washington 25, D. C.

5/ The rate of this color change, we now know, depends upon conditions of temperature and humidity during storage.

was matched, insofar as it was humanly possible, to the leaf in the original standards box for each grade, and checked with photographs and against duplicate boxes passed at previous conferences. This matching of leaf, and hand smoothing and combing of samples to obtain good preparation, finally resulted in such artificial looking samples that in the 1953 revision it was agreed that natural samples would be used, particularly in the higher grades, these to be taken directly from the bale with as little manipulation as possible.

Although no intentional change was made in the level of trash content, there was much discussion in 1946 that indicated a belief on the part of some that the amount of trash in the 1946 standards had been increased for some or all of the grades. In those years color measurements, but no trash measurements, were made on standards bales—all comparisons for trash were made visually by the classer. Therefore, to check whether any inadvertent change had been made in trash content, Shirley Analyzer measurements were made after the conference on samples of bales used in the 1946 standards, and comparisons were made to measurements already in our files for the 1936 bales.

The results in table 1, reported in Textile Research Journal, April 1950, show good agreement between trash measurements for 1936 and 1946 standards bales. A smoothed curve drawn through these data provided specifications for a regularly stepped scale for trash content in future standards. This scale was used in purchasing bales for the 1953 revision of standards.

Table 1.--Percentage nonlint in bales used in cotton grade standards

White grades	Shirley Analyzer percent nonlint				
	1936 standards bales		1946 standards bales		Smoothed
No.	Av.	S.D.	Av.	S.D.	curve
2			2.26	±0.26	2.0
3	2.94	±0.83	2.38	±0.29	2.4
4	3.63	±0.44	3.51	±0.67	2.9
5	3.83	±0.45	3.69	±0.15	3.7
6	5.35	±0.73	5.12	±1.32	5.1
7	8.08	±1.37	7.71	±1.74	7.6
8	11.03	±2.25	11.25	±1.44	11.0
9	18.64	±4.13	15.17	±4.20	17.0

At the 1956 conference, boxes were passed against the 1953 standards. By 1959 we knew that much less leaf was beginning to appear in current grades, and the Department prepared and showed to the domestic industry in a series of local meetings held prior to the next conference a set of grade survey boxes that showed this. This set of boxes, based on a survey of the 1958 crop was shown to the 1959 Universal Grade Standards Conference as a basis for discussing a revision of the standards, particularly of leaf content. But the conference, except for the shippers, was not willing to consider a change.

With no change in standards since the revision of 1953, and in light of the foregoing history, which indicates no intentional change in trash level at any previous conference, it should be clear that the trash content required in today's grade standards remains essentially on the level originally adopted in 1924.

Let us now take a look at methods of judging trash content. The first and still most widely used method is visual judgment against a standard. To help keep standards constant, reference is made not only to original sets of cottons but also to photographs which for many years have supplied a record of the foreign matter content in all copies of the standards. Each box is photographed immediately after its approval by a review committee, and a copy of the photograph is placed in the cover of the corresponding box. But while this provides a record, and a means for comparison, it is not a very useful or satisfactory method, nor does it provide a way to report statistically any measure of trash content.

Since the middle 1930's the Shirley Analyzer has been used to measure the trash content of cotton. It makes an almost complete separation of cotton lint and trash with a minimum of fiber loss. After separation of lint and trash in 100 gram samples, the weight of lint fed into, and delivered from the machine, the weight of visible foreign matter, and of invisible losses, are used as a basis for calculating the percentage of nonlint content. While these weight figures do not take into consideration the nature of the trash, nevertheless they provide the best measure available in the last 25 years for measuring trash content. Another method of trash measurement uses a trashmeter that scans the surface of a sample. Such an instrument is now in use in our Washington laboratories, but measurements made on it do not go back far enough to provide comparative figures for purposes of the present study. We also have measurements of the picker and card waste removed in manufacturing that will be discussed later.

Simple correlations of trash measurements by several methods are shown in table 2. These vary for grade standards bales from r = 0.94 to 0.98. Similar correlations, based on medium staple white cottons in the 1960 Annual Quality Survey, show relationships about 0.70. While the level is higher in one case than the other (because of the narrower range of grades in the 1960 survey), nevertheless both studies indicate that the Shirley Analyzer is as good a means for measuring trash as any now at our disposal.

Table 2.--Trash measurement correlations (r)

	Classer's grade (index)	Shirley Analyzer by weight	Trashmeter		Picker and card waste
			Area	Count	
	(r)	(r)	(r)	(r)	(r)
		Based on standards bales			
Picker and card	-0.94	+0.98	---	---	---
Classer's grade	---	-0.96	---	---	-0.94
Shirley Analyzer	-0.96	---	---	---	+0.98
		Based on 1960 Annual Quality Survey			
Picker and card	-0.69	+0.70	+0.52	+0.54	---
Classer's grade	---	-0.70	-0.70	-0.73	-0.69
Shirley Analyzer	-0.70	---	+0.65	+0.58	-0.70

With this background, now let us examine Shirley Analyzer measurements of trash content made over a period of many years on three separate type studies: on bales purchased for use in preparing copies of grade standards and guides; on grade survey samples for years in which special trash surveys have been made; and on samples used in cotton quality surveys that have been published annually since 1946. Differences may be expected between these studies. Trash measurements on standards bales should be as close to the levels required for standards as it is possible to find, for only when it is impossible to find bales with separate factors equal to those in the standards are other bales considered. On the other hand, trash survey samples represent the complete range of grades in current crops, regardless of the relation of their grade factors, and while not as many samples have been measured as in the more regularly conducted color surveys (because Shirley Analyzer measurements are slower to make), nevertheless in these special trash surveys several thousand samples have been measured. For the annual quality surveys, samples represent only the modal grades in the crop, therefore trash measurements for these studies do not cover all grades.

Trash analyses by Shirley Analyzer percent nonlint content, for white grades, 1936-61, are shown for all three studies in table 3. These analyses make it clear that there is much less trash content in grades of current crops than in those of earlier years. Figure 1, based on data in table 1, shows the average nonlint in standards bales of 1936 and 1946. Figure 2 is based on trash content for grades measured in 1958, 1959, and 1960, shown against the standards curve of figure 1. A comparison of figures 1 and 2 will indicate the relative amount of the decrease in trash content in recent years. 6/ In 1960, in the higher grades there was not much more than half as much trash, by weight, as in samples of the same grades 15 to 25 years ago. Compared to the target curve, grades below Low Middling have leaf about one grade less than formerly, Low Middling about 1.5 grades, Strict Low Middling almost two grades less, and Middling and above even more than two grades. In grades Middling and above a difference by weight of only 1.5 percent trash can mean as much as two grades. Where standards for Good Middling to Good Ordinary vary in trash requirements from 2.4 to 17 percent, today these grades average from 1.4 to 10 percent. In fact, with over 90 percent of the crop equal to or above Low Middling in the white and light spotted grades, this seems to mean that as now ginned, over 90 percent of the crop measures 4.5 percent or less nonlint content. This reduction in trash content seems to have been increasing over the past few years. And preliminary figures, based on a special survey being made this year, indicate that 1961 trash figures will be similar to those for 1960.

6/ More detailed comparisons of these separate studies are made in Report No. 3, "Trash and Color," distributed at the 1959 conference. Copies may be requested from the Cotton Division, Agricultural Marketing Service.

Table 3.--TRASH ANALYSIS: Measured by Shirley Analyzer percent nonlint content, for White grades, 1936-61

Year	SGM 2	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
	Standard curve based on 1936-46 standards bales, used since 1953 as reference for nonlint in grade standards							
Stds.	2.0	2.4	2.9	3.7	5.1	7.6	11.0	17.0
	Based on bales used in grade standards and guides 1/							
1936 1/		2.9	3.6	3.8	5.4	8.1	11.0	18.6
1946 1/		2.4	3.5	3.7	5.1	7.7	11.2	15.2
1950 1/		2.4	3.1	3.6	4.7	7.6	11.7	13.5
1952-3 1/		1.8	2.7	3.5	5.2	8.1	11.5	15.3
1954 1/		1.7	2.6	3.5	4.5	8.0	11.8	13.0
1955 1/		1.8	2.5	2.8	4.5	7.4	11.3	14.8
1956 1/		1.8	2.3	3.1	4.7	7.3	10.7	13.3
1957 1/		1.9	2.4	3.3	4.5	6.1	7.5	13.6
1958 1/		1.9	2.4	3.1	3.9	5.7	7.6	10.8
1959 1/		1.3	1.9	2.1	3.5	6.0	7.0	10.6
1960 1/		1.7	2.1	2.3	3.6	5.8	9.3	11.5
1961 1/		1.6	1.7	2.2	3.1	4.9	9.1	11.1
	Based on grade survey samples for years in which special trash surveys were made							
1947		3.5	4.0	4.6	5.5	7.8	11.0	15.3
1951	1.6	2.2	2.3	3.2	4.3	6.5	9.8	13.5
1952		2.2	2.3	3.3	4.8	6.8	9.6	12.1
1953		2.1	2.5	3.2	4.6	6.7	10.2	13.4
1958		1.7	1.9	2.3	3.4	4.7	6.6	8.7
1959		1.5	1.6	2.2	3.2	4.6	7.6	10.9
1960		1.0	1.4	2.1	3.3	4.3	7.2	8.6
1961 2/		1.5	1.8	2.2	3.2	4.7	6.1	7.9
	Based on samples used in cotton quality studies published annually since 1946							
1946			4.2	4.2	5.2			
1947			3.2	3.7	4.8	5.8		
1948		3.6	3.7	3.8	4.8	5.9	10.2	
1949		2.6	3.3	3.8	4.7	6.0		
1950			2.6	3.0	4.1	4.9	7.8	
1951			2.5	3.2	3.7	6.6		
1952		1.5	2.6	3.2	4.3	5.9	5.4	
1953		1.3	2.5	3.2	4.1	5.5		
1954		2.2	2.4	3.2	4.0	5.5		
1955			2.4	3.1	3.8	5.7		
1956		1.8	2.3	2.8	3.7	4.6		
1957		1.1	2.1	2.6	3.3	4.7	6.7	
1958			1.9	2.3	2.9	4.0		
1959			1.8	2.4	3.0	3.8	4.6	
1960		1.5	1.8	2.1	2.8	4.3	6.5	
1961 3/		1.6	1.7	2.3	3.1	4.1		

1/ Cottons used in preparing copies of standards are from crops of previous year or years; when trash on surface of samples from these bales does not match the standards, each copy is adjusted until it appears equal.

2/ Preliminary estimate based on data through Jan. 15.

3/ Preliminary estimate based on data through Dec. 31.

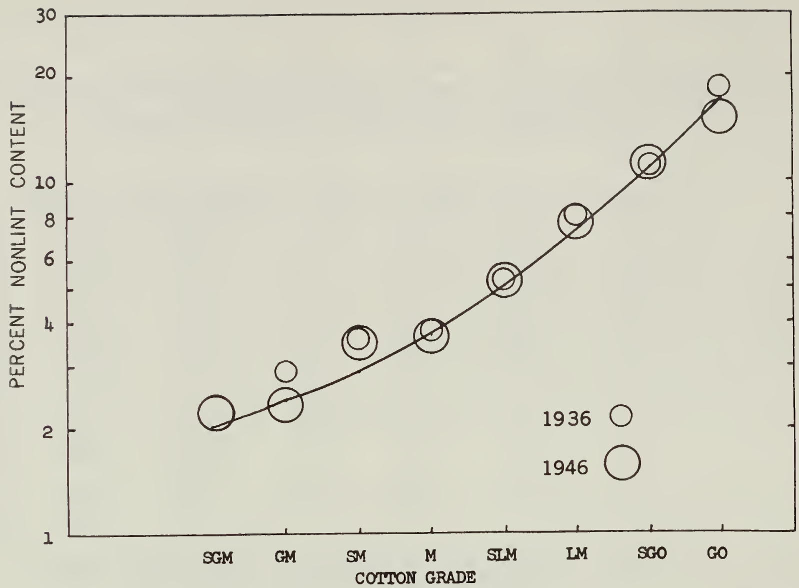


Fig. 1.--Percent Shirley Analyzer nonlint of bales used in 1936 and 1946 white grade standards. Curve based on them is target specification for standards.

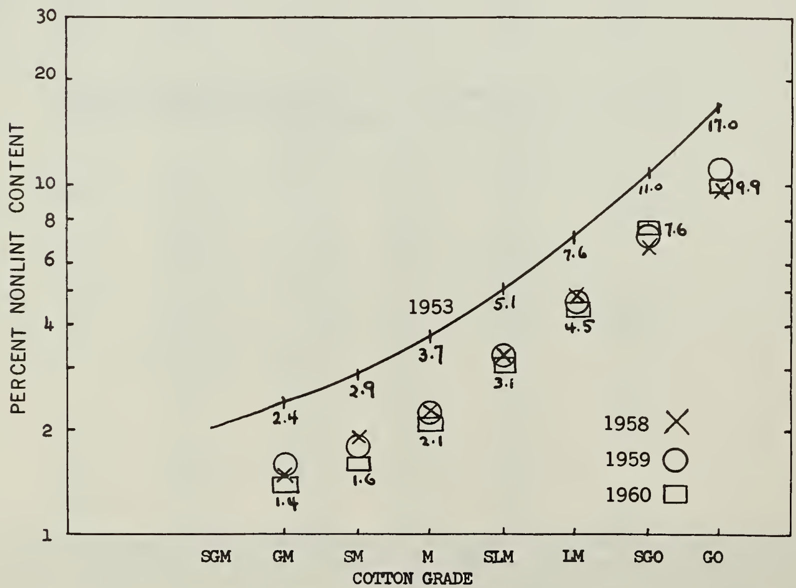


Fig. 2.--Decrease in trash content in recent cotton crops illustrated by data for 1958, 1959, 1960 crops in relation to curve for standards.

Data for manufacturing (picker and card) waste of white grades, taken from the Annual Quality Surveys published 1946 through 1960, are summarized in table 4. They provide a measure of trash that shows a trend similar to that for Shirley Analyzer nonlint content, but on a level about 5 percent higher, since mill waste includes considerably more fiber. Figures 3 and 4 illustrate the relationship between the measurements of nonlint and picker and card waste for 1946-7 and for 1960. Whether measured by Shirley Analyzer or by picker and card waste, this means that gins are doing a much better job at removing leaf today than they did before the days of mechanical harvesting. Bales leave the gin today with even less trash for any given lint color than in the days of hand harvesting! That this extra trash removed shows up in the same amount in both Shirley Analyzer and picker and card waste is evidenced by comparisons that can be made from table 5. In 1960 the decrease in trash amounted to about 1.5 percent for Middling and about 3.1 percent for Low Middling, whether measured by Shirley Analyzer or by picker and card waste.

Differences in terms of grade may not indicate the significance of these facts to some as much as if the same facts were put in another way. They mean that a mill that buys 100,000 bales of cotton would receive the equivalent of 1,500 more bales of lint today for Middling, than it would have received 10 years ago. Much of this is leaf content formerly baled with the lint, but now taken out before baling and shipping.

Throughout this discussion it should be kept in mind that while by weight there are differences of as much as two grades that exist between trash in cottons of today as compared to cottons of earlier years, this may overstate the case in terms of trash visible to the classer. Another point that should be made is that not only has the quantity of leaf changed these past few years, but the kind, for large leaf has almost disappeared in today's cottons, and a classer's impression of amount is considerably affected by this change. A lot of very small leaf looks like more than single large pieces, yet may not weigh nearly so much. The small leaf, however, is much more trouble to remove than single large pieces, so even if it is over-assessed in relation to weight, the visual judgment may in this case more nearly represent the value facts of trash than do the weight figures obtained on the Shirley Analyzer.

As brought out earlier, it is the relation of the three factors of color, trash, and preparation that has changed in the grades of today. Measurements of color and trash, for samples of normal preparation, provide a direct way to establish the grade, and if measurements could be made quickly and precisely for each factor separately, the problem would be easier to solve than now. Measurements of color include trash as well as lint. And the trash includes dust, which weighs very little in the Shirley Analyzer samples yet has a considerable effect on the color measurement. To get a measure of the lint color itself, a cotton sample must be cleaned of leaf and dust. Cotton put through the Shirley Analyzer, measured before and after cleaning, provides information on both color and trash. By a rough rule-of-thumb, in earlier years the improvement in color before and after cleaning on the Shirley Analyzer, for cottons with average leaf and color for any given grade, has been about one grade.

Table 4.--TRASH ANALYSIS: Measured by percent of picker and card waste of white grade samples

Year	SGM 2	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
	Average relationship used as guide for many years for comparing Annual Quality Survey results for medium staple cottons							
Guide	---	6.3	7.2	8.1	9.3	12.5	15.6	18.3
	Based on samples used in cotton quality surveys published annually since 1946							
1946			8.5	8.6	9.7			
1947			7.6	8.5	9.4	12.4		
1948		8.6	7.9	7.8	9.0	10.0	15.6	
1949		7.2	8.7	9.2	10.1	11.7		
1950			7.9	8.1	9.3	11.3		
1951			7.6	8.1	8.9	11.6	12.8	
1952		5.0	6.7	7.2	8.5	9.9		
1953		7.8	6.6	7.2	8.1	9.7	10.0	
1954		6.6	6.8	7.5	8.5	9.6		
1955			7.7	8.2	9.0	11.2		
1956		7.8	8.0	8.1	9.2	10.4		
1957		7.3	7.7	7.9	8.8	9.8	12.5	
1958			6.9	7.4	7.9	9.8		
1959			7.9	8.0	8.6	9.8	10.6	
1960		7.4	6.7	6.6	7.9	9.3	12.3	
	3-year averages, for comparison							
1946-8		8.6	8.0	8.3	9.4	11.2	15.6	
1953-5		7.2	7.0	7.6	8.5	10.2	10.0	
1958-60		7.4	7.2	7.3	8.1	9.6	11.4	

Table 5.--TRASH ANALYSIS BY GRADES: Differences for nonlint and for picker and card waste, by percent weight, for 1960 measurements compared to standard curves

	SGM 2	GM 3	SM 4	M 5	SLM 6	LM 7	SGO 8	GO 9
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
	Shirley Analyzer nonlint content							
1953 std. curve	2.0	2.4	2.9	3.7	5.1	7.6	11.0	17.0
1960 crop		1.4	1.6	2.1	3.1	4.5	7.6	9.9
Diff. in trash		-1.0	-1.3	-1.6	-2.0	-3.1	-3.4	-7.1
	Picker and card waste							
Guide curve - 1960		6.3	7.2	8.1	9.3	12.5	15.6	18.3
Annual Quality		7.4	6.7	6.6	7.9	9.3	12.3	---
Diff. in trash		+1.1	-0.5	-1.5	-1.4	-3.2	-3.3	---

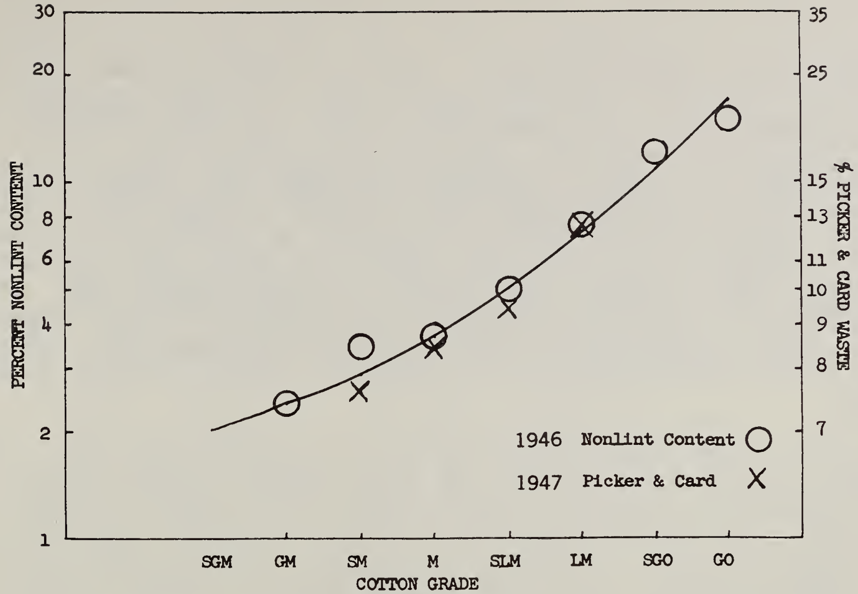


Fig. 3.--Level of trash analysis by Shirley Analyzer and by picker and card waste for 1946-1947 compared to standards curve. (Picker and card is 5 percent above S.A. scale.)

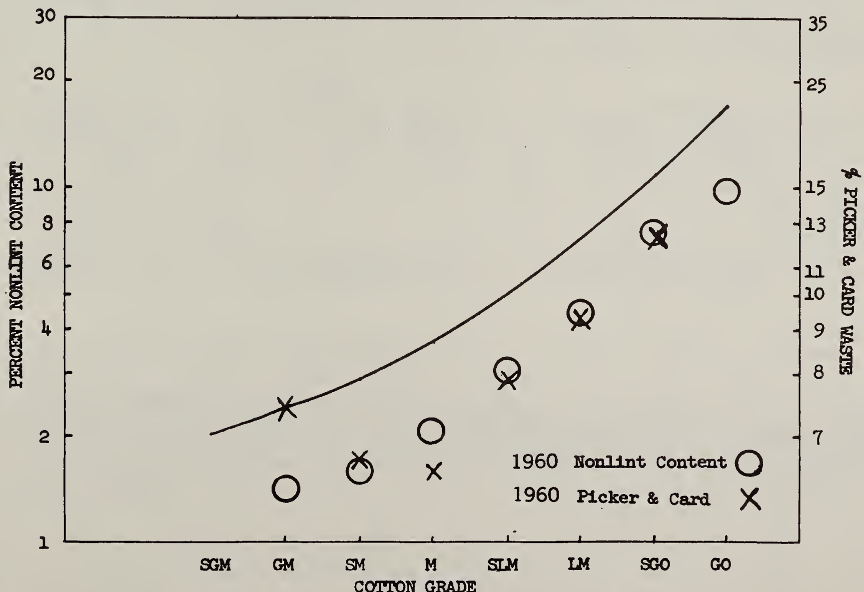


Fig. 4.--Level of trash analysis by Shirley Analyzer and by picker and card waste shows extent of decrease in trash content in 1960 crop compared to standards curve which fit in 1936, 1946, and 1953.

If cottons are put through so much cleaning at the gin that little or no leaf or dust remains to be taken out by the Shirley Analyzer, then there will be little difference in the color measurement of the before-and-after Shirley Analyzer samples. Thus, if a sample measures SLM average color before cleaning, and remains SLM average color after cleaning, it means that the color of the cleaned lint cotton is close to that which in earlier years would have been expected of LM, a grade lower cotton. On the other hand, if a cotton is machine-picked and does not have extra cleaning at the gin to compensate for this, the amount of trash left in it may be high. In such a case the color improvement in before-and-after Shirley Analyzer samples may be as much as two grades in color, for the trash could be equal to that of SGO, and the cleaned lint color equal to SLM. Since the cleaned-lint color is an indication of the amount of field exposure and all the damage associated with that exposure, it is important to know the degree of color improvement that is associated with any lowering of trash content.

Figure 5 demonstrates the amount of color difference, before and after cleaning on the Shirley Analyzer, for white cottons in three studies. These are shown on grade-color diagrams such as are used on the cotton colorimeter. Percent reflectance (the relative lightness or darkness of color) is plotted in a vertical direction, and the degree of yellowness in a horizontal direction. The grade diagram shown is limited to the white grades, the high grades toward the top, low grades toward the bottom. The amount of color difference before and after cleaning for cottons in grades Good Middling to Good Ordinary is illustrated by the length of the vectors. The color of samples before cleaning is plotted at the dashed line in the center of each grade group, and the arrows indicate the average amount of color improvement after cleaning for each grade in the years noted. Roughly speaking, the color improvement after cleaning seems to be about one grade for early years.

In 1958 it seemed as if a trend had started toward less color improvement in many of the grades, but by 1960, except for the high grade bales used in the 1961 standards, this seems to have reversed itself. Preliminary data for the 1961 crop confirm this reversal. They indicate almost the same color improvement today that occurred in early years when more leaf remained in the samples to be removed by the Shirley Analyzer. Since much of the color improvement is caused by removal of dust as well as leaf particles, it may be that in the period around 1958 cottons were so thoroughly cleaned that more of the dust was removed than is today.

If this were not so, and had the trend toward little color improvement in samples before and after cleaning on the Shirley Analyzer continued, it would have meant that cottons graded Middling would have lint color little better than cottons formerly graded Strict Low Middling. In other words, had the 1958 trend continued, and all the dust and dirt as well as leaf particles been removed, then any grade improvement caused by reduced amount of trash would have been offset by a lowering of lint color, which seems to have been true in 1958. And it is the lint color, and all factors associated with the degree of field exposure that caused its deterioration in color, that cannot be improved, either by the gin or by mill. (There is the exception that may seem to give a better color when light spots are blended throughout a bale so that after lint cleaning a bale may be classed White, whereas it would have been Light Spotted without the use of cleaners.)

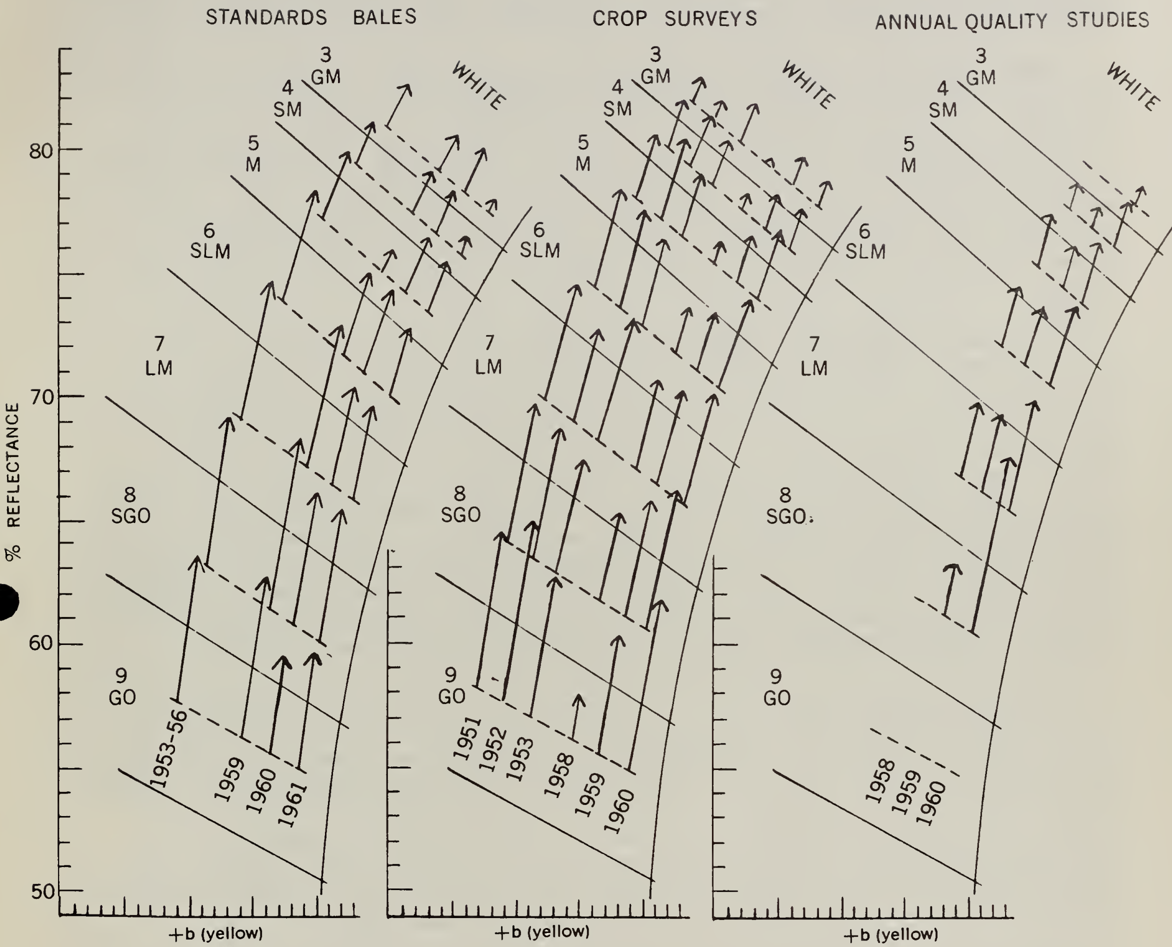


FIGURE 5.--COLOR CHANGE AFTER CLEANING ON THE SHIRLEY ANALYZER, FOR WHITE COTTONS IN STANDARDS BALES, CROP SURVEYS, AND ANNUAL QUALITY STUDIES, 1953-61.

The amount of color change is illustrated by length of vectors; color change caused by cleaning seems to average about one full grade, except that in 1958 there was less improvement in color than most other years. For standards use great care is taken to find bales matching the official standards as nearly as possible in all factors; when this fails, it is necessary to make leaf adjustment in preparing copies of the standards.

The trend toward lower color, that would offset any decrease in leaf, does not seem to be continuing in the bulk of today's cottons. But it is completely clear that relatively more leaf is being removed today from cottons of a given lint color, than was true a very few years ago. The facts are shown on table 3, and the cause quite clearly seems to be the increasing use of lint cleaners that has taken place in the past few years.

This poses a problem in standardization that must be faced. As long as grade covers more than one factor, any change that disturbs the relationship in effect when standards are established on a basis of any particular combination of factors, will make it necessary to average, or offset one factor against another, in applying those standards. The only method that will come even close to providing a basis for standards that can be permanent, and need no changing as the relationship between factors may change is to set scales for separate factors, and then either adopt some method for combining them in a single term, or report them as separate factors. In such a case the Grays could be eliminated, and guide boxes could be made available in which each sample could be labeled with the measurements of whatever separate factors it contained. If bales are not to be found in the crop with all factors of the same grade, then guide boxes for grade could contain samples marked with whatever combinations <u>are</u> found. Either this, or the standards should be changed to fit the color, leaf, and preparation combinations as they are represented in recent crops. While there may be some who may find an economic advantage in allowing the issue to remain confused, certainly it is in the public interest that standards be such that by their use the value of any cotton sample may be assessed as accurately as possible. Prices adjust themselves to the cotton no matter what it is called, and would undoubtedly do so in relation to any realistic change in standards that may be necessary.

It seems certain that no such method as the first one suggested will be adopted any time soon. It, too, would have its difficulties. But in these days of increasing instrumentation, the time is certain to come when standards will become a written specification, and be illustrated by guide boxes that can be measured in accord with standard specifications. Such cottons are available today in our check test program for establishing levels of measurements for testing cottons for fineness and strength, and these check cottons are quite as much a part of our cotton standardization program as the more familiar standards for grade and staple.

The fact that cottons are now being cleaned at the gin more thoroughly than in earlier years does not alter the color of fibers in any given sample. Cleaning out the leaf may make a sample look better in color than the fiber warrants, but it is the fiber color, not the amount of trash, that is an indication of the true worth of a sample. A Low Middling cotton, if it were cleaned of <u>all</u> its leaf and trash, is still a low grade cotton, and will run <u>no better</u> in a mill when the leaf and trash are taken out at the gin, than when they are taken out by the mill. On the other hand, if treated as well by the gin as by the mill in removing the trash, there is no reason why such a sample should run <u>any worse</u> in the mill, unless the mill thereafter "over-machines" it by putting it through cleaning processes that are no longer needed.

SUMMARY

In summary, visual examination for trash content is accomplished through use of grade standards. These combine in single samples the three separate factors of color, trash, and preparation. As long as standards for grade are not changed, these factors when judged separately are on the same level today that they have been for many years. But with a changed relationship of factors in the cottons of current crops, a sample called by a given grade name today may differ from a sample called by the same name yesterday.

Measurements show less trash in current crops than in earlier years. Compared to the grade standards, which were a good fit for 1953 and earlier crops, the trash content in 1960 for grades below Low Middling are more than 3 percent less trash or about one grade less; in Low Middling about 3 percent less trash which at that level means about 1.5 grades; in Strict Low Middling about 2.0 less trash which means two grades; and in Middling and above about 1.5 percent which can mean even more than two grades less trash. These are about the levels of additional trash taken out by use of one to two lint cleaners. Use of lint cleaners has increased rapidly since 1948 when they were found in only 28 gins; today they are found in over 5,000 of the 5,619 gins reported in the United States.

It is the relation of color, trash, and preparation in the cottons of today that has changed since 1953, the year when the present white grade standards became effective. Trash measurements, combined with color measurements made before and after cleaning on the Shirley Analyzer, can tell a great deal about the separate factors. If all trash and dust is cleaned out of a sample, the percentage of trash by Shirley Analyzer should approach zero, and the differences in color before-and-after Shirley Analyzer treatment will also approach zero. This would mean that all dust, as well as all leaf, is removed. And this is not the case. Trash measurements are decreasing but have by no means reached the zero stage, and differences in color before and after cleaning are now only very slightly less, though more erratic, than 8 or 10 years ago.

This difference in trash content creates a problem in standardization. As long as grade consists of more than one factor, anything that disturbs the relationship in effect when the original standards are established will make it necessary to change those standards when they become so difficult to apply that all segments of the trade finally become willing to face the need for changes. While the only permanent solution is establishment of standard scales for separate factors, the adoption more immediately of standards that will "reflect the characteristics of recent cotton crops, insofar as color, leaf, and preparation are concerned" seems necessary.

Prices are based on what is thought to be the value of a cotton sample, no matter how it is called. Standards that do not fit the crop merely increase the difficulty of describing cottons in terms by which their value can be accurately reflected. There is so much less trash in today's cottons than in yesterday's, that standards need changing in order to make it possible to describe grade factors, whether separate or combined, in terms that will no longer confuse, but once again will begin to reflect grade characteristics accurately enough so that the grade aspects of cotton value may be determined in a satisfactory way.

1962 Nickerson, D., Newton, F. E., and Fry, E. G.

COTTON QUALITY RELATIONSHIPS BETWEEN SELECTED MEASURES OF QUALITY AND FIBER, YARN, AND PROCESSING PROPERTIES:

1. Multiple statistical relationships, 1946-1960. Agriculture Information Bulletin No. 257, 137 pp.

2. Simple correlations, means, and standard deviations, 1946-1960. Supplement to AIB No. 257, 248 pp.

Copies of the above statistical reports (blue books) are available on request. The reports are too large to bind with this series.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington 25, D. C.

THE USE OF COLOR AS A MEASUREMENT OF COTTON QUALITY

By Harvin R. Smith*

A paper presented before the American Cotton Congress,
Dallas, Texas, July 12, 1963

As far as can be determined, color has been used as one of the primary factors of cotton quality from the very beginning of commercial trading in this commodity. Throughout the years color measurement has been primarily a matter of judgment by cotton classers. The art of classing cotton is supposed to have started with a Liverpool cotton broker by the name of Joshua Holt, sometime between 1775 and 1785. As early as 1808 such descriptive terms as "good," "middling," "ordinary," and "stained" were being used in England. In America, in the early 1800's, cotton was still classified largely by area of growth. Upland cotton was referred to by such terms as "Texas Blacklands," "Benders," "Peelers," "Rivers," "North Georgias," and "Canebreakers." In 1860 some production areas had only two classifications "good" and "sorry."

When the New Orleans cotton exchange was organized in 1871, grade terms were being used which were almost identical to those in use today. The grade descriptions used by the New Orleans Exchange, however, were not the same as those used in other exchanges and inland markets. There was still considerable confusion in the trade regarding the use of these grade terms. Standardizing these grade descriptions throughout the trade did not make much progress until 1907, when the International Cotton Congress held a meeting in Atlanta, Georgia, and passed a resolution favoring the adoption of new cotton standards for "grade and color." As a result, in 1909, a committee that consisted of "nine men, prominent in various branches of the cotton trade, and three experienced classers from the New York, New Orleans, and Dallas markets," met in Washington, D. C. and approved nine grades of white cotton (figure 1). These nine grades represented the first standards adopted by the United States Department of Agriculture.

Thus, color has been considered to be an important element in cotton quality for over two hundred years, and the classer's eye has been the primary method of color measurement. Even today, the classer is still the most widely used means of judging the color of cotton. Human judgment does have its shortcomings however. While the eye is exceptionally sensitive to small <u>differences</u> in color, it is not so good at judging <u>absolute</u> color levels. For example, anyone who has gone out to buy paint to match the wall at home without taking along a sample or chip of the desired color has experienced this. The classer, with a good standard to guide him, can do a very good job of matching color, for here he is concerned with viewing color differences. It is in the preparation of the standard itself, where the problems of judging absolute color levels arise, that the classer needs help.

---

* Cotton Marketing Specialist, Cotton Division, Standards and Testing Branch.

Figure 1.--Delegates to the first Cotton Standards Conference held in 1909 at Washington, D. C.

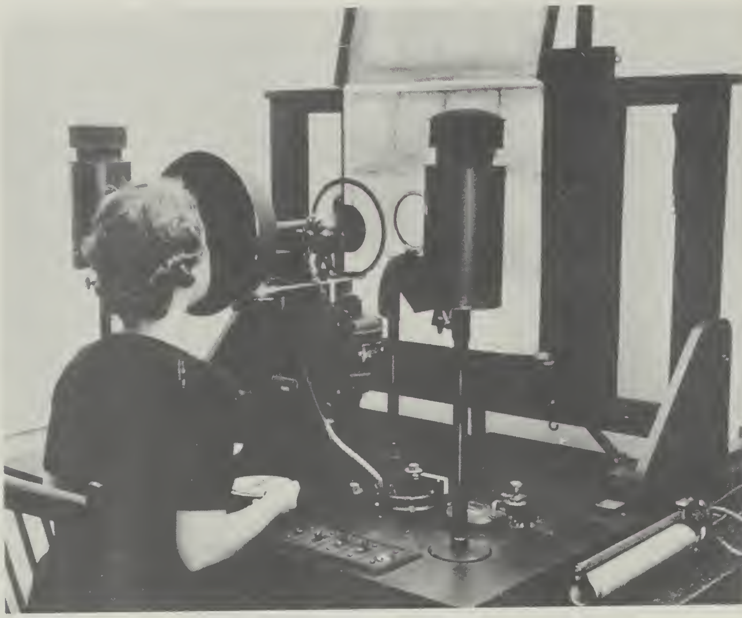
From left to right, Front Row: Joseph Airey, New Orleans; Charles Vetter, Galveston; George Neville, New York; N. Thayer, Boston; J. Martin, Paris, Texas;
Middle Row: Lewis Parker, Greenville, S. C.; Frank Crump, Memphis; J. S. Akers, Atlanta, Ga.; Jules Mazerat, New Orleans;
Back Row: James Taylor, Texas; W. P. Barbot, New York; C. P. Baker, Lawrence, Mass.

In 1927, Dorothy Nickerson, presently head of the AMS Cotton Division's Standardization Section, was assigned the job of developing ways and means of putting cotton standards on a scientific basis through the use of instrument measurements. The first instrument devised to measure cotton color was the disk colorimeter (figure 2). This was an optical device and the measurements depended largely upon the judgment and skill of the operator. The disk colorimeter was used until 1950, when it was replaced by the Nickerson-Hunter Cotton Colorimeter built by Gardner Laboratories. This electronic instrument was developed especially for cotton. It was accurate and "self standardizing," but not suitable for what we now call "high-speed" testing. A more sensitive and sophisticated model of the Nickerson-Hunter Cotton Colorimeter was built by Spinlab in 1959 (figure 3). This instrument now comes in a transistorized model, and is fully capable of measuring thousands of samples per day. This instrument is also adaptable to the "print-out" systems which are necessary for modern high-speed testing.

The feature that distinguishes these instruments as cotton colorimeters is the grade diagram used with them (figure 4). This diagram was developed by the United States Department of Agriculture and is based on measurements of the Universal Standards for grade of American Upland cotton. These measurements are directly related to the fundamental colorimetric measurements which were used in calibrating the scales of a master instrument located in the Washington laboratory of the Cotton Division. We also have developed diagrams for American Egyptian cotton (figure 5) and for cotton linters (figure 6).

The cotton colorimeter is very accurate and precise as illustrated by the following diagram (figure 7). On this diagram are plotted the relative levels of color measurements. The arrows show the extent of one standard deviation from the average for measurements on papers and tiles, repeat measurements on the same sample of cotton, variation within a bale, and variation between bales of the same grade. The data indicate that the instrument itself is capable of very precise measurements. It should be pointed out however, that the colorimeter measures the average color of the sample presented to it. Therefore, it does not tell whether or not a sample is spotted or uniform in color, or whether or not a sample is heavy or light in leaf content. Although these factors affect the color readings, their interpretation still remains a matter of judgment. Because of this precision, we can hold the color levels of the cotton used in the grade standards to very narrow tolerances. The diagram shown in figure 8 is used as a guide to screen prospective bales for use as grade standards. The circles shown represent the color range desired for the various positions within each grade. These ranges represent the "ideal," and it is not always possible to find cotton which will fit every position as accurately as we would like, but the diagram does provide us with a target to shoot for.

As a measurement of cotton quality, color measurements can be used in several ways. Of primary importance, is the effect of cotton color on processing or on the manufactured product. Color is particularly important as a measure of how well the yarn or fabric will bleach or dye. Figure 9 shows



COTTON, USDA - 1929-50 DISK COLORIMETER FOR MEASURING COTTON COLOR

Figure 2.--Early disk colorimeter (Keuffel and Esser) designed to replace the spinning disks (by a spinning optical part) and provide for sample and disk illumination within the instrument; in use by USDA 1929-1950.

Figure 3.--Spinlab model of Nickerson-Hunter Cotton Colorimeter.

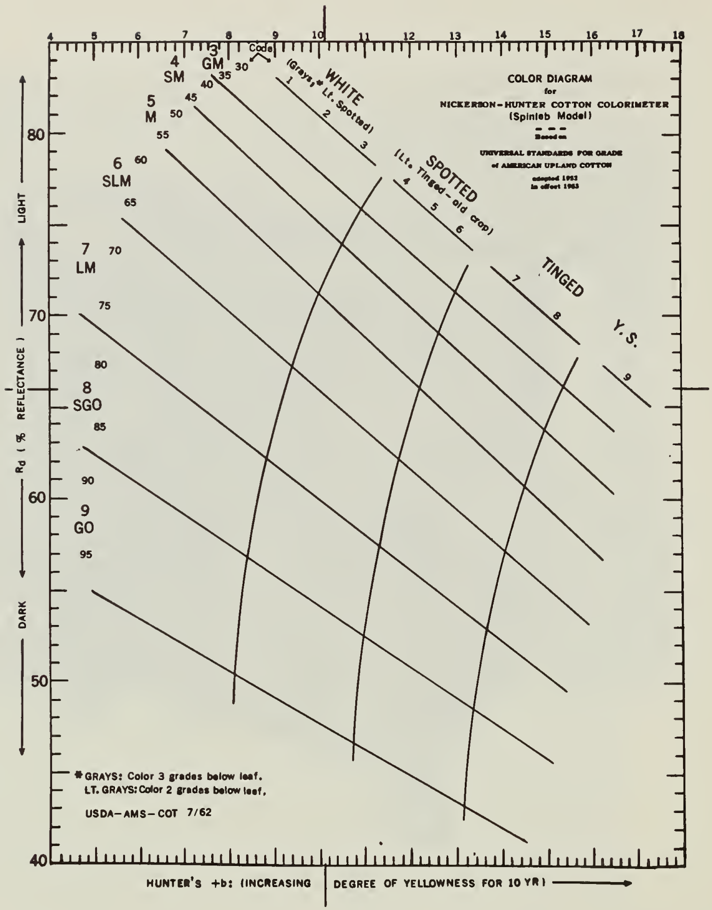


Figure 4.--Color diagram for upland cotton for use with the cotton colorimeter.

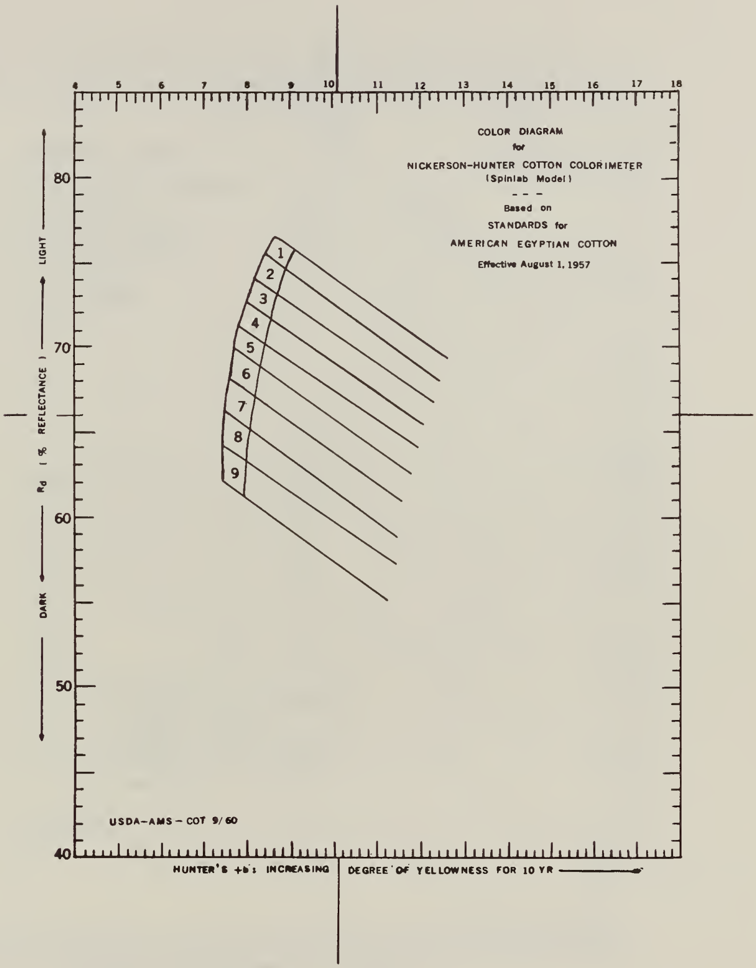


Figure 5.--Color diagram for American Egyptian cotton for use with the cotton colorimeter.

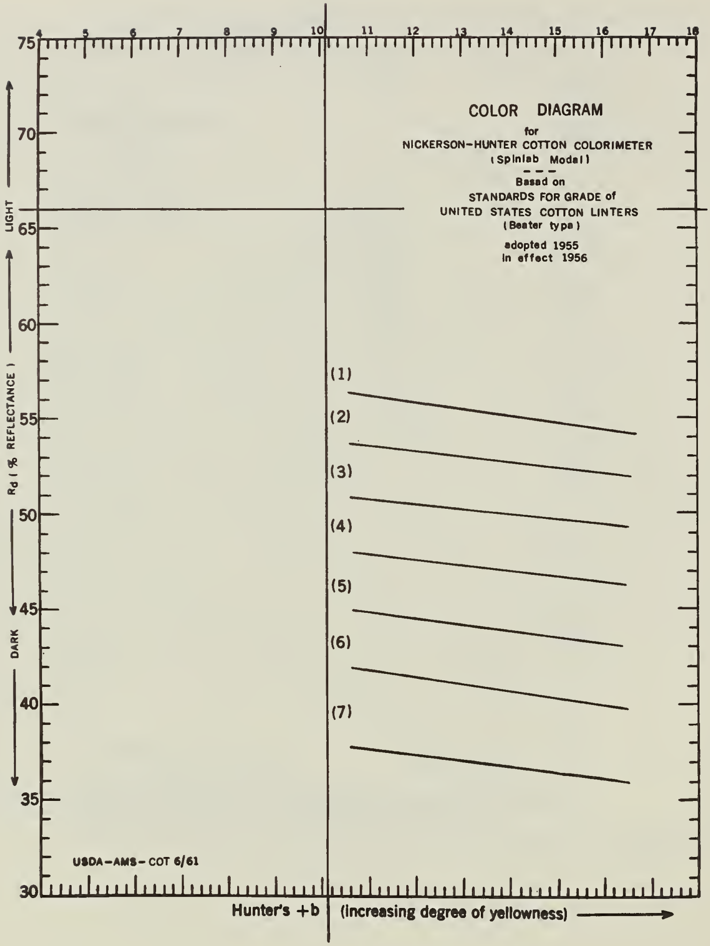


Figure 6.--Color diagram for cotton linters for use with the cotton colorimeter.

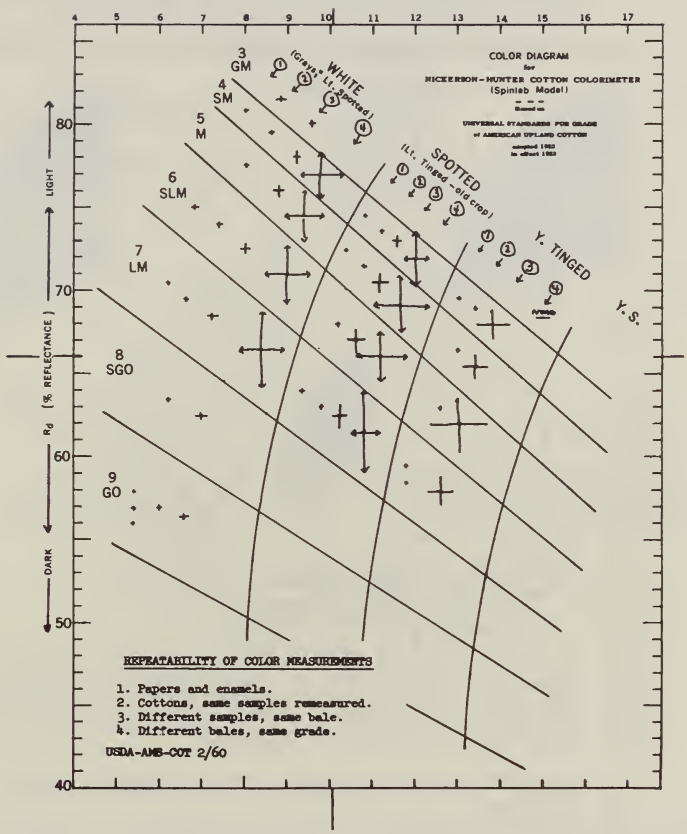


Figure 7.--Precision of measurements on the Spinlab Cotton Colorimeter. The arrows show the extent of ± one standard deviation from the average for measurements on papers, tiles, and cotton.

Guides for purchase of bales for standards. Dots (white grades) and short lines (spots and tinges) represent color positions wanted. Circles and ellipses indicate range of samples expected within purchased bales.

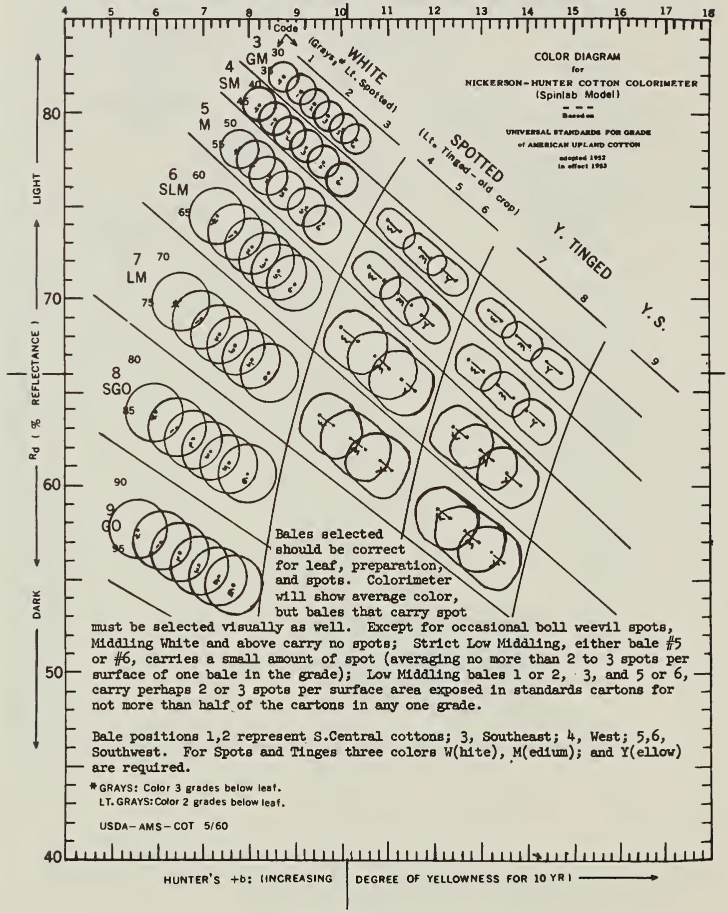


Figure 8.--Color diagram used as a guide in purchasing bales for grade standards.

COLOR OF BLEACHED YARN

(Grade Standards Bales)

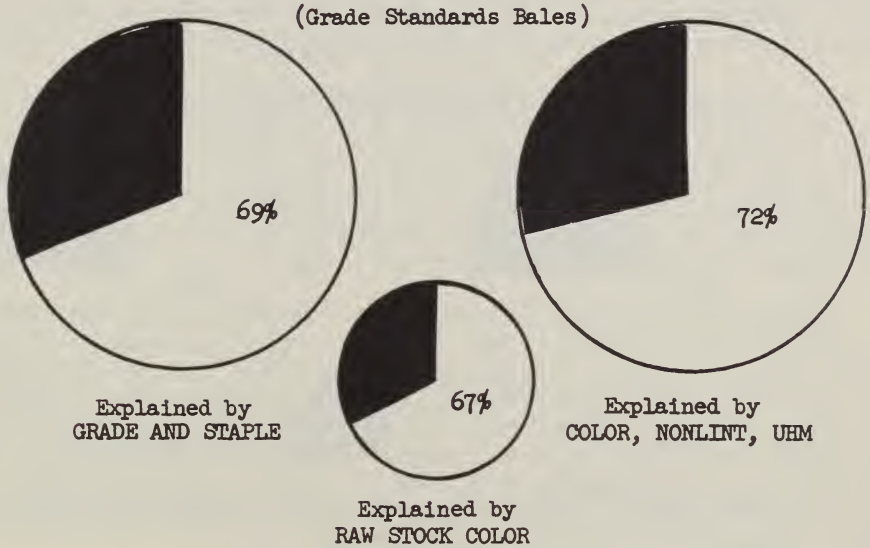


FIGURE 9--VARIATION IN COLOR OF BLEACHED YARN EXPLAINED BY GRADE AND STAPLE; BY COLOR, SHIRLEY ANALYZER NONLINT, AND UHM; AND BY RAW STOCK COLOR (R_d and +b) ONLY.

(Based on test results for 1956 and 1959-60 studies of grade standards.)

the relative importance of grade and staple length and laboratory measurements compared to the effect of color alone in predicting the resulting color of bleached yarn. Figure 10 shows the same type of information relative to predicting the color of blue dyed yarn. In both cases, the color of the raw stock accounts for practically all of the differences observed in the bleached or in the dyed yarn. The data in these two figures were taken from results of fiber and spinning tests made on bales selected for use in the standards. These data therefore, represent the "ideal" or the highest correlation that can be expected since the color of these bales was carefully controlled and includes the full range of grade colors.

Color measurements can also be used to control the color of blends and mixes at the mill. Color control at this point will eliminate much of the variations in grey, bleached and dyed yarns or fabrics. The effects of blending samples which differ widely in color is shown in figure 11. The figure shows that blending equal portions of samples of different colors does not result in a color which is intermediate between the two, but the blend always measures closer to the darker color.

Studying color changes in cotton and its causes is another useful way of using color measurements. The effects of field exposure on cotton color is shown by the example in figure 12. These tests were actually made in 1931, but the results have been replotted on a modern color diagram. In this study, bolls of cotton which opened on the same day were identified and samples picked each week for twenty-seven weeks and measured. Twenty-seven weeks is much longer than cotton is usually allowed to remain in the field before harvesting, but the results show that the color of the cotton becomes progressively darker as the weeks go by.

When cotton is killed prematurely by frost or drought, the result is usually a yellowing of the affected fibers. The pigment in such cotton fibers is a dark yellow color. Therefore, the more of these fibers that are present in a bale of cotton, the yellower and darker it appears. Such cottons are described as light spotted, spotted, tinged, or yellow stained depending upon the amount of the yellow fibers present in the sample.

Another yellowing effect occurs when ginned cotton lint is held in storage. The amount of yellowing which occurs depends upon the temperature, humidity, and the length of time the cotton is stored. Figure 13 shows the rate of color change when cotton is stored in the extreme conditions of both high temperature and high humidity.

In the Cotton Division, color measurements are used in several ways.

1. To maintain the uniformity and a constant level of color in the production of grade standards.

2. To study relationships between the color, leaf, and preparation factors in grade standards as compared to these factors as they exist in current crops. Such studies form the basis for testing the validity of the grade standards and point up areas where improvements are needed.

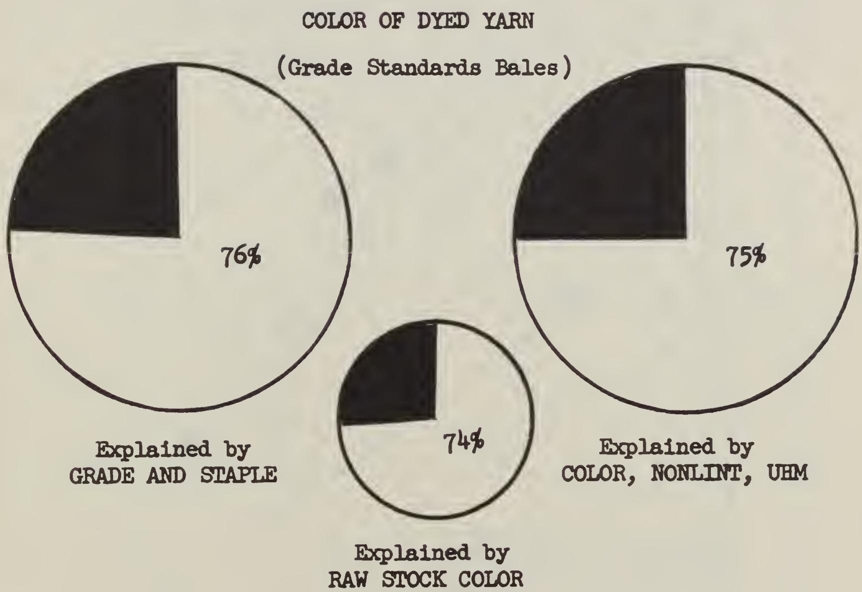


FIGURE 10.--VARIATION IN COLOR OF DYED YARN EXPLAINED BY GRADE AND STAPLE; BY COLOR, SHIRLEY ANALYZER NONLINT, AND UHM; AND BY RAW STOCK COLOR (R_d and +b) ONLY.

(Based on test results for 1956 and 1959-60 studies on [redacted] standards.)

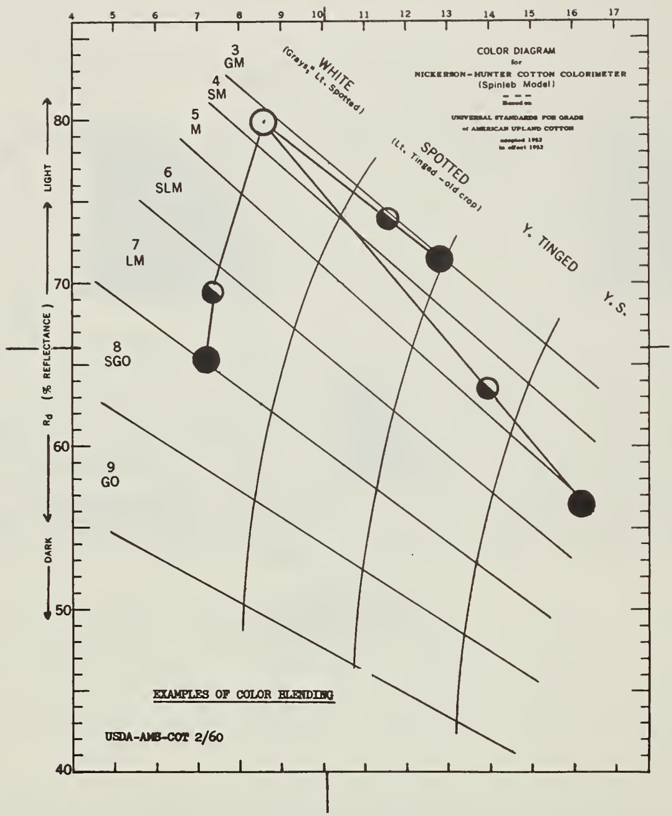


Figure 11.--Effect of blending equal portions of samples of cotton differing widely in color.

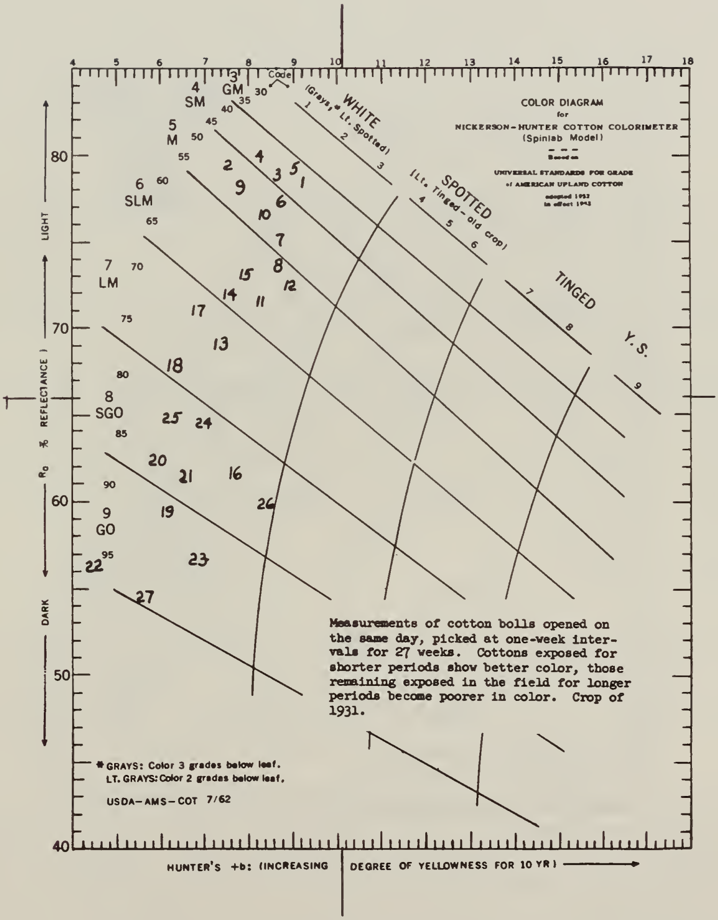


Figure 12.--Effect of field exposure on color of cotton picked at one-week intervals for 27 weeks.

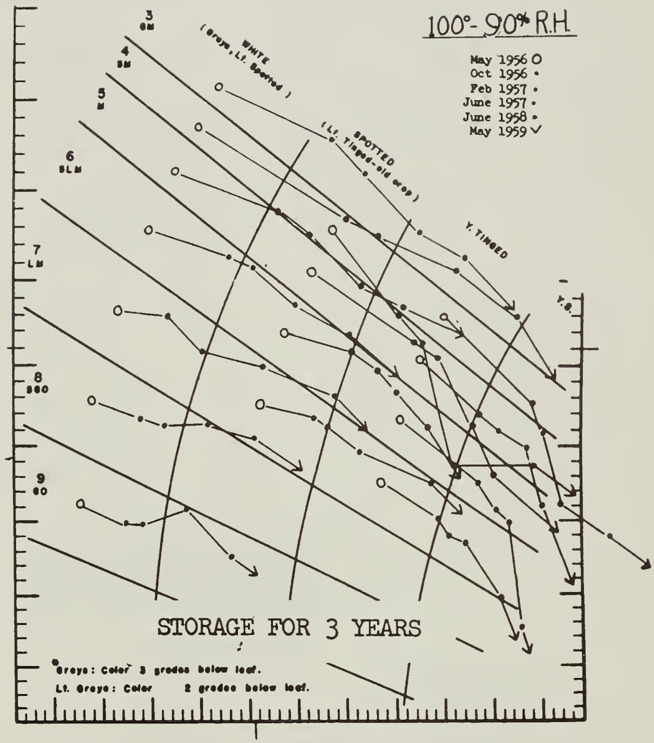


Figure 13.--Three-year color change in storage for samples stored at 100°F., and 90% R.H.

3. To aid cotton classers in maintaining a constant level of grade classification.

Aside from the measurement of color itself, and the effect of color on the end product, color is indicative of other factors in cotton which are usually associated with it. A few of these factors are shown in table 1. The table shows an expected high correlation between color and grade; a slight correlation between yellowness and micronaire reading; more correlation between reflectance and fiber strength; and a considerable degree of relationship between the color of cotton and its waste and trash content as measured by the Shirley Analyzer. The correlations shown for yellowness are very low and some are insignificant because of the sample distribution.

Table 1.--Simple correlation analysis of color measurements with selected fiber properties. Annual Quality Survey, Crop of 1962

Color Measurements		Grade	Micronaire	Strength 1/8" gauge	Waste S. A.
		Index	Reading	Index	Pct.
Reflectance	R_d	+.82	+.14	+.40	-.58
Yellowness	+b	+.24	+.21	-.15	-.26
Composite	Index	+.85	+.16	+.38	-.62

There are other less tangible relationships between various fiber properties and cotton color. Some of these are very difficult to measure and perhaps there are others which we cannot now measure at all. Such factors as fiber length, sugar content, pH, and certain forms of biological damage all seem to be related, more or less, to cotton color.

In summary, cotton color is a very important measure of cotton quality. This is shown by the fact that color has been a primary factor of grade for well over 200 years. It is important, not only for the effects of color itself as shown by the color of the manufactured product, but it is also important for the many fiber properties which are associated with color that exert a significant influence on processing performance or on the quality of resulting product.

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

ACHIEVEMENT OF LIGHTING STANDARDS FOR THE GRADING OF COTTON

By Dorothy Nickerson, Cotton Division

(Paper prepared on invitation of Marketing Section, Association of Southern Agricultural Workers, for their meeting February 6-8, 1956, Biltmore Hotel, Atlanta, Ga.)

Contents

Lighting Important to Cotton Classification

Cotton classification as practiced by several thousand men in this country is the art of describing the quality of cotton in terms of grade and staple length in accord with official standards. For grade, classification is based on appearance and is accomplished by visual inspection of the color, leaf, and preparation of a sample, with a mental integration by the classer of these three factors into a single grade description. This means that the quality and quantity of lighting in a cotton classing room becomes a matter of considerable economic importance, for not only are grade factors judged visually, but the length of staple also.

This season the United States Department of Agriculture already has classed twelve and a half million bales, over eleven and a half million of these for farmers under the Smith-Doxey Act which provides free classification and market news service for those organized in groups to promote the improvement of cotton. If lighting varies enough to make judgements off by even one-half of a grade, or by 1/32nd inch in staple length, it could make a very great dollar difference when

applied to the very large number of bales that are classed each year. For example, this year (1955 crop) the average grade and staple is about Strict Low Middling, 1-1/32 inch cotton. On a basis of 1955 loan differences applied to 500-pound bales, a half grade below this average would mean $6.62 per bale; 1/32nd inch staple shorter would mean $2.50 per bale. Multiplied by the millions of bales classed, this becomes millions of dollars!

There is also the problem in naturally daylighted rooms of expense for time lost in poor weather when there is a lack of sufficiently good classing light. This is a serious consideration, particularly during peak loads, for not only is classification delayed, and more help necessary to accomplish the same amount of classing in the fewer hours of good lighting, but space requirements are greater in order to take care of storage of samples that pile up during such periods.

This year two of our 35 classing offices classed over a million bales each and four others well over a half a million each. Whether such large-scale classing is done in a government or commercial office it becomes imperative to do everything possible that will help to keep classing on a continuous as well as on a uniform basis. Our investigations in the field of lighting have been made with this as our purpose.

Natural Daylight Skylights, 1914-1937

The United States Department of Agriculture has provided leadership in setting specifications for lighting cotton classing rooms for many years. As long ago as 1914 what is known as a Government-type skylight was first developed in connection with services under the Cotton Futures Act. The first slide (figure 1) illustrates a Washington classing room of this type. It was built in 1937 and illustrates the best development up to that time for lighting a classing room. Plans for this room and those that preceded it served many years as guides for builders and architects designing classing rooms. (In this country we seldom have calls for these plans today, but we still have requests from overseas.)

Artificial Daylighting Studies

In 1919, as far as we can determine, artificial daylighting was first tried out in our offices. With the cooperation of Norman Macbeth, Sr., a specialist in artificial daylighting, this early experiment was made in our New York office, and while it proved that cotton could be classed under artificial light of satisfactory daylight quality, it was unsuccessful chiefly because daylight lamps of those days were awkward and uncomfortable to use when placed in position to provide a sufficient quantity of light. The classer needed more freedom to move about with his sample.

USDA - WASHINGTON CLASSING ROOM, NATURAL SKYLIGHT
Prior to 1949 this was best type of lighting

Figure 1.

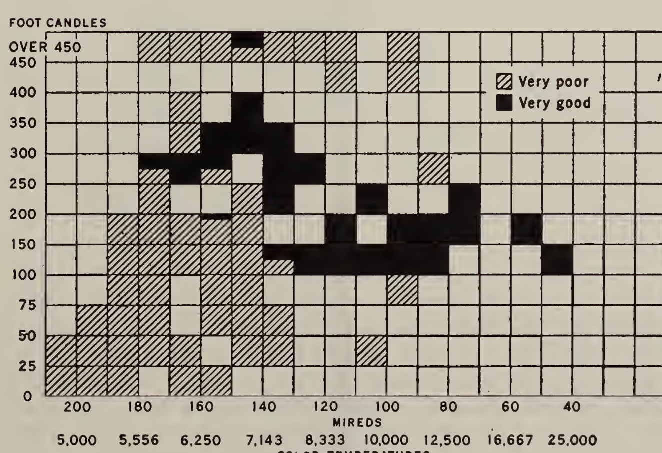


Fig. 2 -Footcandle and color temperature data taken at selected color matching stations in four large textile mills. Conditions for color matching called very good shown against those called very poor.

The next step came in the early 1930's when, in connection with studies of natural daylighting of classing rooms, a survey was made of the amount and distribution of light in all of all USDA's larger classing rooms. This was basic information, needed before any serious attempt could be made to provide specifications for lighting either large or small areas with artificial daylighting. The results, shown in the next slide (tables 1 and 2), clearly indicate that amount of

TABLE 1.—Average of Maximum and Minimum Illumination in Footcandles Read Hourly over 30-day Periods in June and December, Using a Weston Photocell Meter for Certain Sky and Classing Conditions (For Horizontal Plane).

Classing conditions	Sky conditions					
	Clear		Slightly cloudy		Overcast	
	June	December	ne	December	June	December
Very good	108-150	41-50	126-155	52-65	100-150	115-150
Good	118-145	51-60	147-174	64-77	204-252	116-122
Fair	109-149	37-48	138-158	65-75	137-160	80-91
Poor	119-148	31-36	140-168	65-74	99-118	61-70

TABLE 2.—Average of Maximum and Minimum Illumination in Footcandles for Classing Designated as "Good."

Classing room (location)	Weather conditions					
	Clear		Slightly cloudy		Overcast	
	June	December	June	December	June	December
Washington (new bldg.)	180-190	34-45	220-235	45-55	220-250	....
Washington (old bldg.)	120-140	40-50	200-230	65-75	250-275	55-65
Austin	120-150	80-90	130-160	150-160	270-310	175-190
Memphis[1]	85-100	55-60	110-120	50-60	....	....
Memphis[2]	140-240	80-105	220-295	70-100	200-250	....
Houston	130-140	50-60	140-150	75-85	150-160	....
Charleston	130-150	45-55	110-115	50-60	250-350	140-150
Atlanta	60-70	75	130-140	60-75	....	90
Savannah	130-150	....	140-150	60-70	....	....
New Orleans	70-90	12-13	80-110	14-19	90-125	....
Dallas	180-220	30-40	150-185	55-70	....	....
Stoneville	70-100	54-60	140-200	75-90	200-300	120-125
AVERAGE	118-145	51-61	147-174	64-77	204-252	116-122

[1]Office of the Board of Supervising Cotton Examiners.
[2]Local classing office.

light is not the only factor in determining whether color classing conditions are good or poor. Only for overcast sky conditions in December are the average foot-candle readings highest for "Very Good" classing conditions and lowest for "Poor" classing conditions. For clear and slightly cloudy conditions in both June and December and even for overcast days in June, the highest foot-candle averages are not selected for "Very Good" classing conditions. While the amount of illumination was the only factor measured instrumentally during these tests, later studies corroborated the opinion reported at that time that choice of classing conditions indicates that quality of light may be even more important than amount of light once a minimum amount has been reached. It is quite generally established that color matchers, cotton classers included, prefer light from an overcast or "covered" north sky and it therefore seems probable that the data shown are the result of averaging whatever amounts of illumination happened to be associated with the best liked quality of illumination,

that is, the most favorable energy distribution. Light from a clear blue sky usually was called glaring yet the data show that the amount of illumination on clear days is well below that of slightly cloudy or overcast days.

In 1937 we became actively interested in exploring the possibilities of developing specifications that would provide satisfactory auxiliary lighting units for use in the classification or grading of a number of agricultural products in which color is an important factor. Our early work was with filtered incandescent tungsten, using special glass filters over high wattage tungsten filament lamps in order to filter out the excess energy in the long wave length end of the spectrum of incandescent tungsten to obtain a result as close to the energy distribution of daylight of a lightly or moderately overcast sky as possible. While this study was in progress the fluorescent lamp was announced and in 1939 through the generous cooperation of one of the larger lamp companies a special unit of fluorescent lamps, combining daylight and blue lamps to give adjustable color temperatures, was supplied for this study before fluorescent lamps became generally available for public sale. Early tests on both the filter and fluorescent types were made in three classing rooms, in our own Washington and Memphis classing rooms, and in the Houston classing room of Anderson, Clayton & Co.

It seemed obvious to us that in these tests high color temperatures should be avoided, and our early trials of the installation shown in the next slide were first made with the color temperature of C.I.E. Standard Source C (the international standard for "average daylight") at about 6700K as a goal. But this, as has been reported elsewhere, was found slightly too yellow in color since our classers pronounced conditions "satisfactory" rather than "good" under 6700K conditions. Actually the cottons looked very slightly too yellow under Source C when compared to their appearance under the daylighting conditions which they preferred, and it was necessary to go to a bluer light at 7500K to obtain a minimum color that would give us fully satisfying results. Preference was given to filtered tungsten on the basis of both technical requirements for a daylight substitute and by practical classing tests in all three rooms used in the test.

Later, in a study of the illuminant in textile color matching, measurements were made at color matching stations of several cooperating mills of amount of illumination at the matching surface and of the color temperature of the natural daylight. These measurements, paired with subjective descriptions of the lighting conditions by color matchers on a 5-step scale from "Very Good" to "Very Poor," are illustrated on the next slide (figure 2). As indicated, conditions called "Very Good" required a minimum color temperature close to 7500K for a minimum of 100 foot-candles, although as the foot-candle level increased the accompanying color temperatures decreased. At 100 foot-candles 7500K seems about the minimum for "Very Good"

lighting conditions, but the range extends to include higher color temperature levels. Conditions called "Very Poor" seem to be those which either combine low color temperature with low foot-candles, or those which include very high foot-candles (above 400-500 foot-candles) at any color temperature.

The technical information developed in these studies has been reported to the Illuminating Engineering Society and to the Optical Society of America and published in their journals, the early studies in a series of three papers, 1939-1941, and the later study in two papers, 1948, reported by a committee of the Inter-Society Color Council of which the speaker then was chairman.

On completion of the 1939-1941 studies specifications for artificial daylighting were established to include: Diffuse reflection over a relatively wide area from a wide angle source; color and energy distribution close to that of a moderately overcast sky at 7500K; 60-80 foot-candles on the classing tables. This amount was well above the minimum of what was called "Very Good" for December conditions of natural lighting in our classing rooms, but it was set above the minimum so that even after a considerable reduction in lumen output of lamps there would be enough light for classing. For color work with dark samples it was realized that this specification for amount of light would have to be increased, but we kept our specifications for cotton to a minimum, for in those days it was not known whether it would be practical even to meet this 60-80 foot-candle request--a request that is very modest by 1956 standards!

As a result of these tests, units of artificial daylight made in the form of 4-foot cotton classing skylights, each equipped with six 1,000 watt tungsten filament lamps over each of which was placed a Macbeth filter of Corning's No. 5900 Daylite glass, were installed beginning in 1941 in many classing rooms of the Cotton Division. Their use was no more than spasmodic, for while a majority of classers seemed to feel that they could class satisfactorily under artificial light, the small area illuminated by single units was generally discouraging. Moreover, the use of the natural daylight skylight had become so much a symbol of the trade that for the most part this feeling initially hampered the use of artificial daylighting units. Our Lubbock office, with four units hung in a Quonset hut at the Texas Technological Institute, began to make real use of the artificial lighting, and a few commercial firms began to make similar installations. One such pioneer installation was made by T. D. Truluck of the Deering Milliken Mills in Union, S. C., not far from here.

Then came World War II. It was not easy to find space, nor to build new classing rooms with daylight skylights. So gradually there began a definite and increasing trend to class cotton under artificial daylighting, particularly by commercial concerns. In some cases it proved so satisfactory that skylights were covered or removed entirely. By December of 1949 more than 15 firms in Memphis, Tennessee, alone

were using artificial lighting for much, and sometimes all of their classing. Until 1950 practically all installations were of the filtered tungsten type. However, the initial cost and the inefficiency of the unit which resulted in excess heat and high operational upkeep, particularly when lighting whole rooms, placed it beyond the reach of the majority of users except for auxiliary purposes. Nevertheless, its superior technical qualifications were proved satisfactory in practice, and the cotton industry became convinced that it was an advantage to class under the uniform light of installed artificial daylighting. They were now ready to look around to find a less expensive substitute for filtered daylighting!

Development of fluorescent-plus-tungsten filament lighting

Our offices in Memphis began to try out installations of luminous-indirect and louvered direct-indirect fluorescent luminaires. Most of them provided so much better amount and diffusion of light than the cotton man expected that he began to realize how practical artificial lighting might be. In fact, it looked so good to him in the beginning that he often overlooked the importance of factors such as color quality of the light or the maintenance problem that precludes the use of open fixtures in the extreme dust-catching conditions of cotton classing rooms.

Credit for installation of the first large-scale classing room using Examolites must go to Anderson, Clayton & Company's Atlanta office. There Mr. George A. Levy, in charge of constructing a new classing room at Atlanta, decided to make his own tests. If a suitable way of providing artificial lighting employing fluorescent lamps could be found he was willing to try it out on a fairly large scale in their proposed 70 by 80 foot classing room. A temporary series of different types of fluorescent units were installed and used, and the combination found best was one of daylight fluorescent lamps to which blue fluorescent lamps were added, with white paper used to reflect and mix the illumination until a suitable combination was found at the classing surface. The manufacturer who had installed all of the filtered type of artificial lighting for cotton classing called Mr. Levy's attention to an enclosed examining unit which contained the same sort of combination of daylight and blue fluorescent tubes, but with tungsten added to take care of a lack of red energy in the fluorescent tubes. The original of this examolite had several 50-100-150 watt tungsten lamps arranged so that different amounts of tungsten could be switched into the combination at will. The combination finally selected was three 40-watt daylight fluorescent lamps, two 20-watt blue fluorescent lamps, and four 25-watt tungsten filament lamps. Based on spectral energy curves of the combined lamps it was found that the correlated color temperature produced by this combination was very close to 7500K. Trial installations were made on a number of patterns with units hung six feet above the classing tables

on 8, 9, and 10-foot centers. The results--which confirmed calculated data--indicated that when units were hung at six feet above the table they should be in rows centered no more than 8 feet apart in order to supply reasonably even illumination at table height. On the basis of these trials, the units in the new classing room installation were hung on 8-foot centers, nine feet from the floor. The results were so successful that all thought of providing an auxiliary natural skylight for buyers who might prefer natural daylighting was abandoned. A picture of this early installation is shown in the next slide (figure 3). Directly under the lamps, except at the ends of the rows, there was a foot-candle level of 80 when the writer measured it some time after installation, and halfway between rows the lighting level nowhere fell below 70 at table height.

Since that day when Anderson, Clayton's Atlanta classing room was completed--only about six years ago--much has happened.

In December 1950, Frank C. McClendon of our Dallas office prepared a report for the information of our USDA offices on the use of artificial lighting for classing rooms as it stood at that time. He reported first-hand inspection of twelve different installations by commercial concerns scattered from the Carolinas to Texas, in each of which practically all of the classification was being done under artificial lighting. At that time more classing rooms probably were equipped with the filter type of artificial daylighting than with the examolite type. The next slide (figure 4) provides an illustration of a large and very good type of filtered artificial daylight installation at Cannon Mills in Kannapolis, N. C. However, most of the installations visited were of the examolite type for as Mr. McClendon explained, "while these (filter-type) units have an advantage over the fluorescent units of more nearly meeting the spectral energy distribution requirements for an artificial daylighting at 7500K, they are so much more expensive that we have not considered them in planning lighting installations for entire classing rooms." He went on to report that practically every type of working condition was present in the installations visited and even the ones with poor environment had satisfactory illumination for classing. He reported, too, that of the firms visited, practically all had come up with the same findings as to amount of illumination and spacing of units, but that there was some difference of opinion as to color treatment of surrounding conditions. Since there is considerable shifting of classers within the Cotton Division's offices the report strongly recommended that all of our installations should be as near uniform as possible. The report provided detailed descriptions of each installation visited and included recommendations and purchase specifications for any subsequent purchases by the Cotton Division.

Gradually, as new offices were built, or as moves had to be made to new quarters, several of our classing rooms began to be equipped fully with artificial lighting by use of examolites. There was much

ACCO - ATLANTA, GEORGIA 1950
First large-scale Examolite Installation

Figure 3.

54-FOOT FILTER-TYPE ARTIFICIAL DAYLIGHTING INSTALLATION 1950

Figure 4.

initial grumbling, for most classers felt sure that they would not like such lighting. But working under them convinced even our most conservative classers. I believe it is safe to say that today no one in the cotton business in this country would think of lighting a new classing room with anything but artificial lighting. Typical of this is the fact that in April 1953, the Atlantic Cotton Association at its Thirtieth Annual Convention in Savannah adopted a resolution suggesting to the United States Department of Agriculture that in order to "help insure more uniform classification throughout the classing season regardless of weather conditions and other interferences they (the United States Department of Agriculture) consider......installing in their cotton classing rooms throughout the cotton belt, modern classing lights." The resolution was incorporated in the report of the Association's Grade and Staple Standards Committee, N. D. Darden, chairman, and "was unanimously adopted."

In the matter of installations it cannot be said that the government led the way. We did assemble in our laboratories the basic technical information that was necessary to establish specifications which practically all of the early installations followed, but after the experience of our laboratory with the poor reception by our own offices of the filter-type lighting we recommended (which afterwards was found successful, though expensive, by a very considerable number of early users of artificial lighting) we, in the laboratory, were rather inclined to hold back until our classing offices themselves began to ask for this new lighting. This they have now done, as is indicated by the summary in table 3 of the lighting situation in classing offices of the Cotton Division existing, or in process, January 1956. Thirty-five of our thirty-seven classing rooms are equipped, or will be this year, with artificial lighting. 1/ A number of these rooms are illustrated in the next few slides (figures 5 to 8). Note arrangement of tables at right angles to lighting in the Greenwood office, and parallel to lighting in the Little Rock office.

The next slides illustrate a few non-government installations, the first, one of many large and busy commercial classing rooms in Memphis, the Bakersfield classing room of the California Cooperative Association (figure 9), the classing room in Italy of the Milan Arbitration Board (figure 10), and an experimental classing room set up by Great Britain's Raw Cotton Commission in Liverpool. Use of artificial lighting is just beginning in countries outside of the United States, so that the Milan installation, and a number of other small ones in Europe, in South America, and in Japan, may be said to be pioneers.

1/ In Washington, where International Grade Conferences are held, both artificial and naturally daylighted classing rooms are available. Since European delegates to these conferences are not accustomed as yet to exclusive use of artificial lighting, the large daylighted classing room has until now been kept as it is.

Table 3.-Lighting in classing offices of Cotton Division, A.M.S., existing or in process January 1956

Office	Location	Approx. dimensions	Usable square feet	No. of Examolites: Rows	No. of Examolites: Per Row	No. of Examolites: Total	No. tables at peak	Table Pos. P or R 1/	Date installed, or target	Notes
A. SOUTHEAST AREA										
Atlanta, Ga.	1020 Crescent Ave.N.W.	38 x 63 1/2	2413	4	13	52	16	R	April 1956	Under construction
Augusta, Ga.	(Corner Druid Park & Wrightsboro Road	38 x 52	1976	4	10	40	12	R	July 1956	Bids received
Birmingham, Ala.		38 x 64	2432	4	13	52	14	R	Aug. 1956	Plans in process
Columbia, S. C.	2628 Millwood Ave.	38 x 64	2432	4	13	52	14	R	Dec. 1955	
Montgomery, Ala.	702 Madison Ave.	40 x 53	2120	4	11	44	12	R	July 1953	
Raleigh, N. C.	Caswell Square	58 x 84	4872	—	skylight	—	7	—	—	
Washington, D.C.	12th & C Sts. S.W.	40 x 38	1460	4	8	33 2/	—3/	P	Aug. 1951	
B. SOUTHCENTRAL AREA										
Alexandria, La.	City Park	31 x 44	1364	2	10	20	4	R	May 1952	
Blytheville, Ark.	500 W. Chickasawba St.	32 x 65	2080	4	13	52	14	R	May 1956	Under construction
Greenwood,Miss. 4/	405 W. Market St.	35 x 70	2450	4	14	56	16	R	July 1955	
Hattiesburg,Miss.	East Seventh St.	16 x 26	400	2	4	8	2	R	Aug. 1954	Seasonal office *
Hayti, Mo.	108 S. 3rd St.	48 x 50	2425	6	10	60	12	R	July 1954	
Jackson, Miss.	220 W. Pascagoula St.	32 x 53	1696	4	11	44	9	P	Jan. 1955	
Little Rock,Ark.	210 Gaines St.	35 x 70	2450	4	14	56	18	P	Aug. 1955	
Memphis, Tenn.	1328 Monroe Ave.	80 1/2 x 38	3059	4	17	68	20	R	Oct. 1952	Area classing office
Memphis - BSCE 5/	1328 Monroe Ave.	60 1/2 x 38	2299	4	13	52	—5/	P	Oct. 1952	
New Orleans, La.	U. S. Custom House	20 x 44	880	2	9	18	4	R	July 1955	
Prentiss, Miss.	Prentiss, Miss.	13 x 24	312	2	4	8	2	R	Aug. 1954	Seasonal office *
Winnsboro, La.	802 Adams St.	40 x 49	1960	4	8	32	7	R	Aug. 1952	
D. SOUTHWEST AREA										
Abilene, Texas	———	32 x 61	1952	4	10	40	12	P	June 1956	Plans in process
Altus, Okla.	325 W. Commerce	49 x 53	2597	6	10	60	16	P	July 1951	
Austin, Texas	———	32 x 61	1952	4	10	40	12	P	July 1956	Plans in process
Corpus Christi,Tex.	218 S. Staples St.	39 x 49	1911	4	10	40	12	P	June 1955	
Dallas, Texas	1907 Ross Ave.	49 x 50	2450	6	10	60	18	P	July 1955	
Galveston, Tex.	701 P.O. Bldg.	27 x 58	1566	3	10	30	9	P	July 1954	
Harlingen, Tex.	706 North H St.	32 x 49	1568	4	10	40	12	P	June 1955	Seasonal office
Houston, Texas	600 Texas Ave.	34 x 56	1904	3	10	30	9	P	Jan. 1951	
Lubbock, Texas	2414 Avenue E	64 x 77	4928	9	13	117	45	P	July 1951	Present space
" "	———	83 x 88	7304	10	21	210	60	P	Sept 1956	Plans in process
Okla.City, Okla.	408 Northwest Fifth	30 x 49	1470	4	10	40	11	R	July 1954	
Waco, Texas	Highway 6 - Marlin Rd.	26 x 41	1066	2	4	8	6	P	Sept 1955	Seasonal office *
S. WESTERN AREA										
Bakersfield,Calif.	430 - 27th St.	90 x 100	8960	8	9	72	24	R	Sept 1951	
Carlsbad, N.M.	105 N. Canal St.	50 x 90	4500	4	7	28	8	R	Sept 1953	
El Centro, Calif.	690 Broadway	29 x 55	1595	3	9	27	8	R	July 1954	
El Paso, Texas	517 U. S. Courthouse	36 x 47	1700	4	10	40	10	R	Aug. 1954	For Upland cotton
" "	"	20 x 64	880	2	5	10	4	P	Aug. 1948	BSCE, supervision
" "	"	20 x 20	400	1	2	2	1	P	Aug. 1954	For Am.Egyptian Cotton
Fresno, Calif	3533 E. Tulare	64 x 124	7600	4	13	52	20	R	Aug. 1953	
Pecos, Texas	510 East Third St.	38 x 42	1450	(3 3	6 4)	30	7	R	Sept 1953	Seasonal office *
Phoenix, Ariz.	304 W. Indian School Rd.	50 x 62	3100	—	skylight	—	16	—	—	

1/ P = Tables set parallel under lighting units; R = Tables set at right angles. 2/ One row with 9 units.
3/ Room used for preparation of standards. 4/ Additional classing is done in building of Staple Co-op. Assoc.
5/ Board of Supervising Cotton Examiners. Classing room used for supervision samples.

USDA - MONTGOMERY, ALA. 1953

Figure 5.

USDA - GREENWOOD, MISS. 1955

Figure 6.

USDA - LITTLE ROCK, ARK. 1955

Figure 7.

USDA - BAKERSFIELD, CALIF. 1951

Figure 8.

CALIFORNIA COTTON COOPERATIVE ASSN. 1953

Figure 9.

MILAN, ITALY - ARBITRATION ROOM 1953
Assn. Cotoniera Italiana

Figure 10.

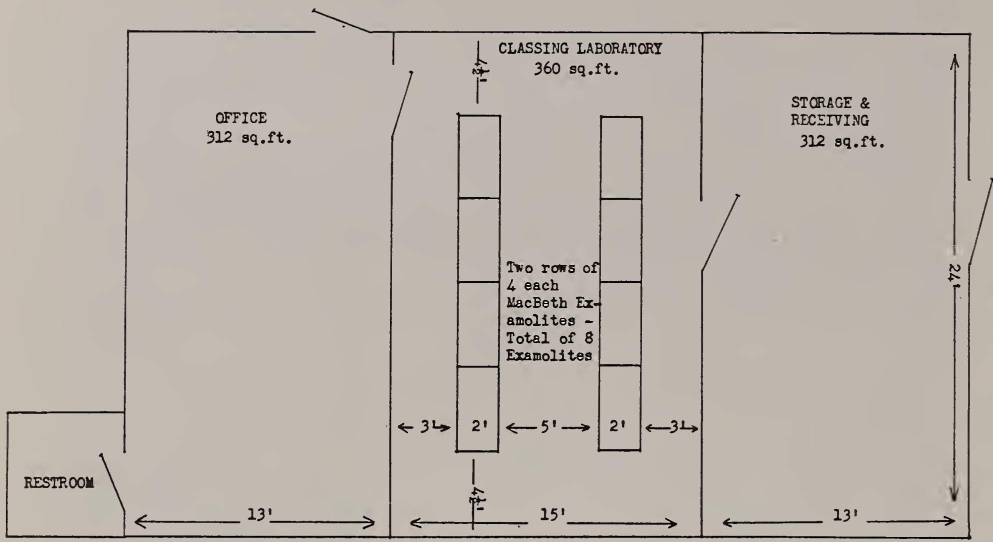
Uniform lighting in classing rooms all over this country, even over the world, would be a big step toward uniform classification. But uniformity in lighting can only be had if such installations follow the same general specifications. Lamps abroad are not the same as ours, and care should be taken to see that technically the overall result meets the same specifications for quality as well as quantity of lighting. Otherwise it is quite conceivable that we could have variation in lighting by use of such a variety of light sources and their combinations that we could be as bad, or even worse off, than by lighting differences in daylighted classing rooms. Unfortunately, the advantages of standardization were foreseen in the beginning by some of the larger cotton firms as well as by the United States Department of Agriculture, and as a result practically all large installations in this country have followed the same general specifications.

Development and Improvement of Specifications, 1950-1956

Developments and improvements have been made in these specifications in the past five years, with a more efficient diffusing glass, a single new examolite tube that combines in one tube the fluorescent colors that formerly had to be obtained by use of both "daylight" and "blue" fluorescent tubes, an improvement that allows use of four tubes of the same size instead of a combination of two sizes as in the early units. Improvement in use of tungsten lamps that will provide very similar color of light but will last many times longer is now under way, for it has been a constant annoyance to have to replace tungsten lamps many times oftener than fluorescent lamps. (Fluorescent lamps have a rated life of 7,500 hours while small tungsten lamps are closer to 700 hours.) There has been improvement also in the specifications for placing the lamp units, moving them up a foot higher (10') and placing them in rows that are on centers a foot closer (7'). This means that no longer is there difficulty in meeting the 60-80 foot-candle requirements, for these newer installations measure close to 100-110 foot-candles on installation. Since the lumen output of the lamps will decrease as much as 30 per cent during its rated life, this means that even with lamps that have burned several thousand hours, providing the tungsten lamps are kept renewed, the illumination level should meet the requirements of the specification.

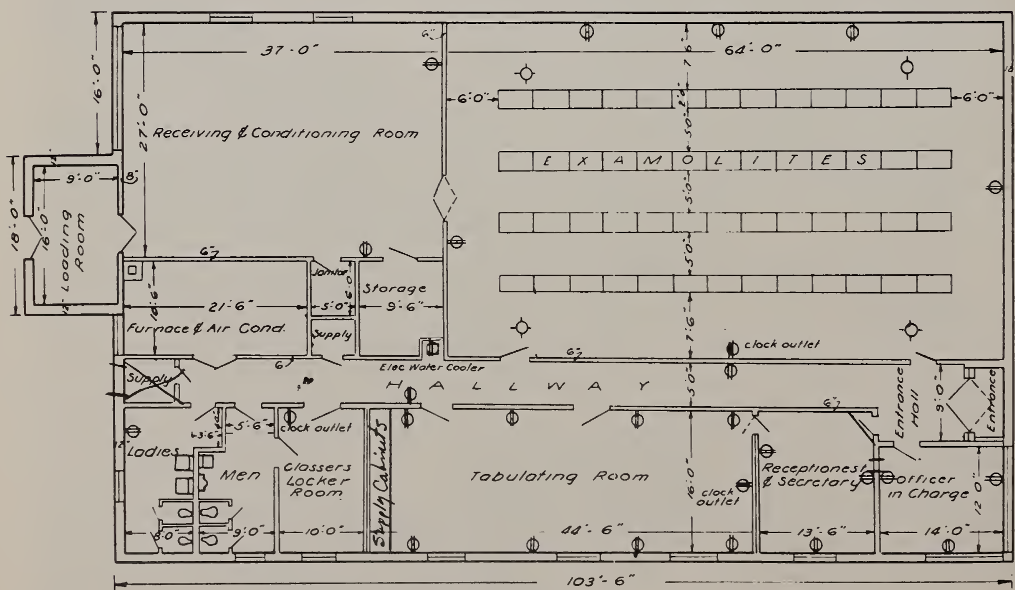
Specifications used at the present time for purchase of lighting units for use in cotton classing rooms of the United States Department of Agriculture are included in Appendix A, page 28.

As regards specification for the pattern to be used within a classing room for installation of units, this is gradually settling down to a fairly definite plan. Slides are shown (figures 11, 12, 13, and 14) for layouts for several different sized or shaped classing rooms, complete with receiving, shipping, and office space. All units are now set 10 feet from the floor, in rows on 7-foot centers. When working under natural skylights classers became used to working



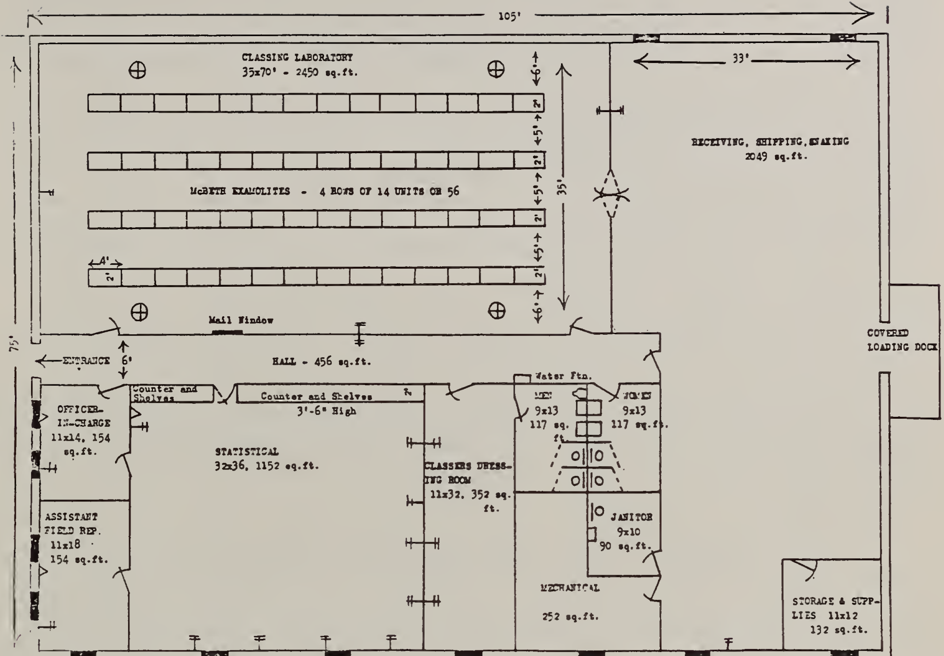
PLAN FOR SMALL TEMPORARY CLASSING OFFICE SPACE. (PRENTISS, MISS.) 7/54

Figure 11.



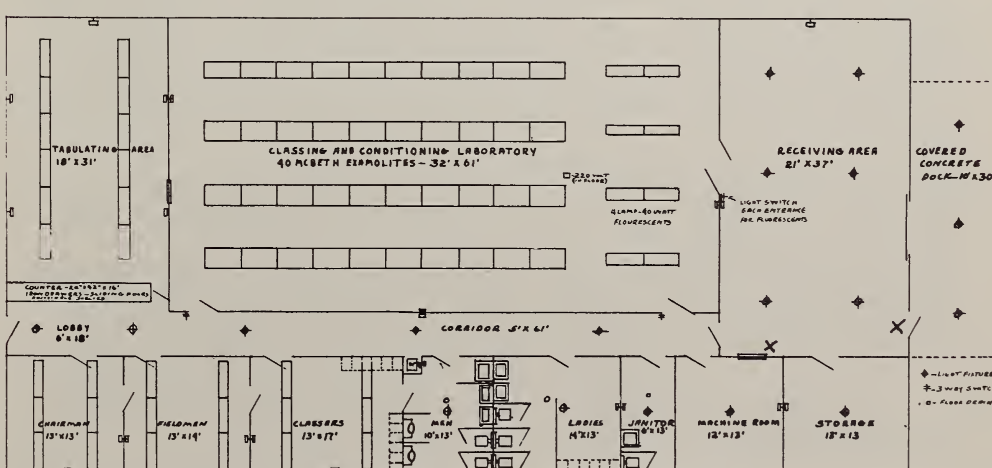
RECENT PLAN FOR COTTON CLASSING OFFICE, SOUTHEASTERN AREA OF COTTON DIVISION

Figure 12.



PLAN OF LITTLE ROCK, ARKANSAS, CLASSING OFFICE, SOUTH CENTRAL AREA OF COTTON DIVISION

Figure 13.



PLAN FOR COTTON CLASSING OFFICES FOUND ADAPTABLE FOR SOUTHWESTERN AREA OFFICES OF COTTON DIVISION

Figure 14.

at tables set parallel to the direction of the skylight, and this is necessary also for the filtered incandescent type installations which usually are installed in single rows. But with examolite units the entire room can be lighted, and if this is done uniformly enough over the whole room it should make no difference how tables are placed.

An efficient general plan for our offices is illustrated in figure 14, a sketch for Abilene, which is the same as that used for Oklahoma City, Corpus Christi, Harlingen, and new space for our Austin and Lubbock offices. Our Southwest Area office advises that they have found it very good for their area. It lends itself easily to increase or decrease and can be reversed if property locations restrict its present arrangements. Lubbock, for example, has been increased to 17,500 square feet on this identical plan. (They also point out that the two places marked with a cross, while they seem to be minor, have proven extremely valuable. The single door for ordinary traffic from the receiving room to the outside and the location of the return air and automatic roll type filter in the receiving room rather than in the hall, eliminate a tremendous quantity of lint that accumulates in the hall where the return air is through the hall or corridor.)

For a single table no less than three units, set end-to-end, should be used. The minimum specification for lighting a small room is two rows of four units each. A plan for such a room is illustrated in figure 11. Larger installations provide better conditions for it is easy to see that the longer the rows, the more good classing space there will be available, since the light under the ends of each row, and under the end row of lamps, is less than that in the remainder of a completely illuminated room. An even number of rows, preferably a minimum of four for an average sized room, increasing to six, eight, or ten for larger rooms, allows efficient use of space for tables such as are used in our offices. They can be placed either parallel to the direction of the lighting, or at right angles. When at right angles under four rows, one row of tables is placed so that one end of each is under row 2 of the lamps, the tables extending back to row 1, and another row of tables is placed so that one end of each is under row 3 of the lamps. The classer stands at the head of his table, one at row 2, the other at row 3. As he looks along his table the lighting will be quite uniform as far as the center of the row of lighting over the far end of his table, beyond that it will fall off unless there is an additional row of lighting. With tables set at right angles to the lighting, it takes two rows to light his table adequately, and then it will light it uniformly only for the 7-foot distance between centers of the rows of lighting. Refer to figures 1, 4, 7, 9, and 10 for tables set parallel, and to figures 5, 6, and 8 for tables set at right angles to lighting.

It should be pointed out that for these large installations, air conditioning is specified along with the lighting.

Color of Surrounding Conditions Important in Lighting Installations

The color of walls, ceilings, floors, furniture, and even of the product itself (if it covers a large area when laid out for classing) has a considerable effect on the lighting in a room. There is an effect on both the physical amount of light reflected, and on the psychophysical effect of what illuminating engineers call "brightness contrast." Since there is a considerable shifting of classers from one office to another in the Cotton Division, especially during the peak of each classing season, it is important that conditions in all Government installations be kept as uniform as possible, not only with regard to the type of installation, but in the surrounding conditions also.

Classing rooms should be painted a neutral color so that no one chromatic color, whether of cotton or of any other product, will be flattered or discounted more than another. Neutral colors may be light or dark, from white through a series of light to dark neutral grays, on to black. The lightness, or the reflectance of the gray that should be used in any room depends on the amount of light coming into it and reaching the classing surface. In rooms lighted by natural daylight the wall and ceiling color can be a lighter gray for rooms with a small skylight, or those not too well lighted by window space, than for rooms into which a great deal of light enters, as from an 80-foot skylight. When there may be an excess of light the gray wall color, especially the color of the upper wall facing the skylight, may be a gray as dark as Munsell N 6/. This is because there is sometimes so much light from a large skylight (in June, for example) that the light would be glaring, and produce glaring contrasts if it were not reduced by a fairly dark color on the wall. The darker the gray on the walls, the more the light falling on that wall will be absorbed. Conversely, rooms where there is only a moderate amount of light should have walls painted a light gray so that more of the light can be reflected back into the room.

For rooms with artificial lighting, such as those lighted with wall-to-wall examolites, the surroundings should be light (near-white) in color in order to conserve the lighting and to reduce brightness contrasts as much as possible. The following specifications are those which we use:

<u>Walls</u>, preferably Munsell Neutral 8.5/, certainly not darker than Munsell Neutral 8.0/;

<u>Ceilings</u>, white or as near white as possible, certainly not darker than Munsell Neutral 8.5/;

<u>Floors</u>, preferably a light gray, about Munsell Neutral 7.0/ (although darker floors may be satisfactory);

Mats, on which a classer stands, should be black (so they may be used as a background for stapling);

Tables for classing, black, although gray may be satisfactory. (When in use tables are covered with white cotton which keeps the light reflectance high during periods of use.)

The color of the grays above is specified in Munsell color notation by reference to the Munsell Value Scale. For those not acquainted with this notation, an inexpensive scale in 18 steps of neutral gray, may be obtained from the Munsell Color Company, Inc., 10 East Franklin Street, Baltimore 2, Md. We supply such scales to our own USDA cotton classing offices, with a copy of these recommendations. The address is given so that others may obtain a copy, unless they find the following description sufficient for their purposes:

> The Munsell Neutral Value Scale consists of a series of neutral grays in visually equal steps from Black (at 0/) to White (at 10/). Munsell Neutral 7.0/ designates a light gray, 8.0/ and 8.5/ designate increasingly lighter grays, 9.5/ is a very good white.

The grays used in the classing room should be neutral grays, showing no trace of any hue; that is, they should not be yellowish grays, greenish grays, or bluish grays.

We might note also that at least one paint company (in Dallas) has produced a flat wall paint to meet the N 8.5/ specification, calling this color a "Cotton Grading Gray."

Maintenance of Lighting Equipment

One of the things that must be impressed upon users of installed lighting is that lamps and equipment must be properly maintained in order to hold the proper level of lighting. It is not enough to install good lighting; it must be maintained. Otherwise we shall not long continue to have uniform lighting conditions in the various offices in which our cotton is classed. We quote at this point suggestions for maintenance taken from "Housekeeping Hints for Classing Offices" prepared last spring by Frank C. McClendon of our Southwest Area office.

> The proper maintenance of the classing lights is essential to adequate lighting. Your lighting troubles are not solved merely by the installation of Examolites. Any electrical or mechanical device needs attention and preventative maintenance has proven to be the least expensive. Due to varying word loads, weather conditions and the periods of time the classing lights are used it is not practical with the information at hand to definitely set up a maintenance schedule. However, each office should effect their own schedule and keep some type of record on maintenance and designate one individual to be responsible for this activity.

The following suggestions are offered:

1. Daily inspection.
   (a) Immediately upon turning the lights on a quick visual inspection should be made to see if all tubes and bulbs in each unit are burning. Perhaps it would be well for the classer to assume this responsibility for the lights in his area as soon as he goes to his table.

   (b) Once or twice during the day another check should be made for burned out tubes and lamps.

2. Replacement of Tubes and Lamps.
   (a) The expected life of the fluorescent tube is from 7,000 to 7,500 hours or approximately three seasons' use. The 25-watt incandescent lamp is 700 hours, but this may vary if current fluctuates considerably (a new longer life lamp is now under investigation as a substitute for this tungsten incandescent lamp.)

   (b) Tubes found flickering or lamps burned out should be replaced immediately.

   (c) Use the proper type of tube or lamp for replacement.

   (d) Chart your classing lights and indicate on each light the initial date of installation, the foot-candle reading and date of tube replacement. One season's record of this type will give you a working base that may be used as a guide for replacements. More than one season will be required to set up a definite replacement schedule. An elaborate record is not intended but only a notebook record at the time a tube is replaced. There is some doubt as to the necessity of keeping a detailed record on each unit. Certainly it should not be a burden.

   (e) Foot-candle readings should be charted or recorded at the beginning of the season and at least weekly readings should be made throughout the season to determine the light intensity.

   (f) Lumen output of lamps declines as the life expectancy is approached and when tubes reach a 30% decline from the original reading they should be replaced. Readings should be taken at the time of installation, and before and after washing, in order to have a base from which to figure the natural decline.

3. Cleaning the Fixtures.
   (a) Tight construction prevents an over amount of dust collecting but some dust does collect in the more dusty areas.

   (b) Cleaning both the inside of the unit and the glass thoroughly at the beginning of the season and periodic inspection should determine how often the unit should be washed completely.

   (c) Inside of unit and the glass should be washed with a wet cloth, thoroughly dried and left sparkling. Do not just wipe out. Water used in washing should be changed often and rags should be rinsed out frequently

   (d) A weak ammonia solution should be adequate.

   (e) Occasionally, when there has been an unusual amount of dust, under side of glass may be vacuumed and then wiped off with a wet rag and thoroughly dried. Do not smear as a streaked glass can cause light irregularities.

   (f) The outside of hanging fixtures should be vacuumed before cleaning the glass.

4. The upper plates inside the mixing chamber should be removed and the ballasts inspected once per season. Low voltage tends to cause ballasts to overheat and bleed. The resulting melted asphalt will run down inside the unit.

5. It is not intended that the care of the lights should be a burden, but periodic inspections and cleaning are necessary to maintain the lights at adequate intensity and in the best operating condition.

Spectral Energy Distribution Basic to Color Grading

There is one very important matter that should be called to the attention of a group such as this. This relates to the importance of the spectral energy distribution of lighting to be used in color work. For cotton we have found that the combination of fluorescent and incandescent lighting described is quite satisfactory for classing the colors of cottons, most cottons being near-white. It does not follow that it will be equally successful for all agricultural products, nor that it will serve all purposes. It may be entirely satisfactory for inspecting or sorting purposes, but unsatisfactory for initial grading of a product.

My own work in lighting has been chiefly with its technical color phases, the details of which are not easy to explain. Indeed, few lighting engineers are acquainted with the spectral energy requirements for color grading and inspection work. Because we have such a variety of new light sources the problem becomes even more complicated. For example, there are on sale today, in addition to special lamps, five different white fluorescent lamps made regularly by practically all large lamp manufacturers: two Warm Whites, two Cool Whites, and a Daylight white. The Warm Whites are yellowish, at a color temperature near 3500K; the Cool Whites are whiter, at a color temperature near 4500K; and the Daylight white is about 6500K, the color of average daylight. The Warm and Cool Whites come in a Standard lamp, which places emphasis on high lumen output, and in a DeLuxe lamp, in which the emphasis is on better color rendition.

The fact that there is a pair of Warm and a pair of Cool Whites illustrates my point about spectral distribution. The color of each pair of these lamps is about the same; they look alike; one cannot tell them apart by looking at a pair of lighted lamps. However, the spectral energy distribution, although it may average to the same color for each pair, is quite different in some parts of the spectrum. The next slide (figure 15) illustrates this; the DeLuxe lamps clearly show more energy in the red end of the spectrum than the Standard lamps. And this means that for many products the color will appear different under the Standard lamp than it will under the DeLuxe lamp of the same color. The amount of color shift in a sample will depend on its own capacity to absorb and reflect the different wave lengths of the spectral energy that may fall upon it. For cottons, shown in the next slide (figure 16), the curves are smooth and regular, with no evidence of distinctive absorption bands which may be present in other products.

I do not expect here to give you a lesson in these matters. There is not time. But their importance is so great to any real understanding of what should be expected of lighting for color grading that I do wish to give you at least some insight into the problem.

First, what are we after in lighting for color grading?

Usually, for grading of agricultural products, we are after lighting under which products will appear the same as they would under that type of daylight which is usual or preferred for grading the product. If the product is graded in sunlight, then a satisfactory substitute illumination should have the same relative energy distribution, wave length by wave length, as there is in sunlight; if, as is more usual, a product is graded in a north window or under a north skylight, with preference for a lightly or moderately overcast sky, then a satisfactory substitute illumination should have the same relative energy distribution as that of a lightly overcast sky from the north.

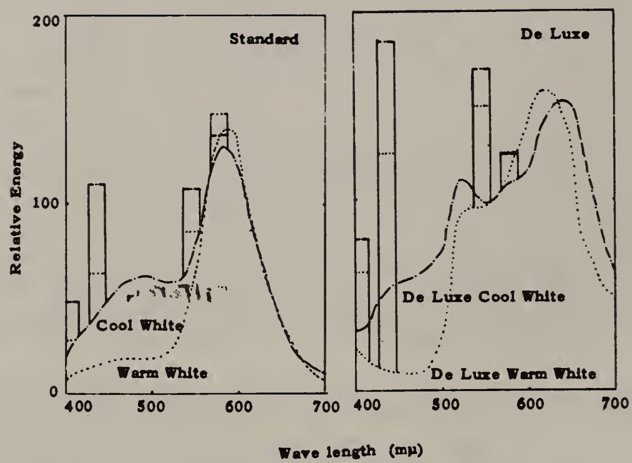


Figure 15.--Typical relative energy curves of two sets of fluorescent lamps. One set is Standard, with maximum lumen efficiency, the other is De Luxe, with more energy in the long wave length region (red end) of the spectrum to provide better color rendition.

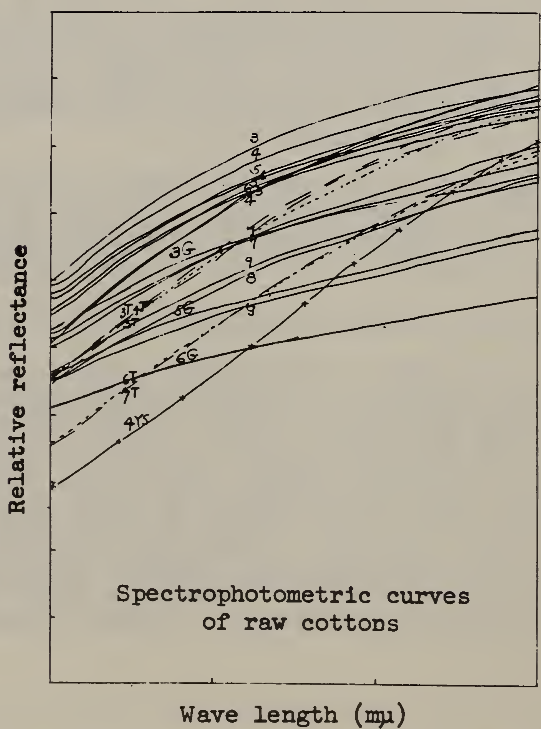


Figure 16.--Spectrophotometric curves for cotton samples, high to low in grade and gray to yellow stained in color class.

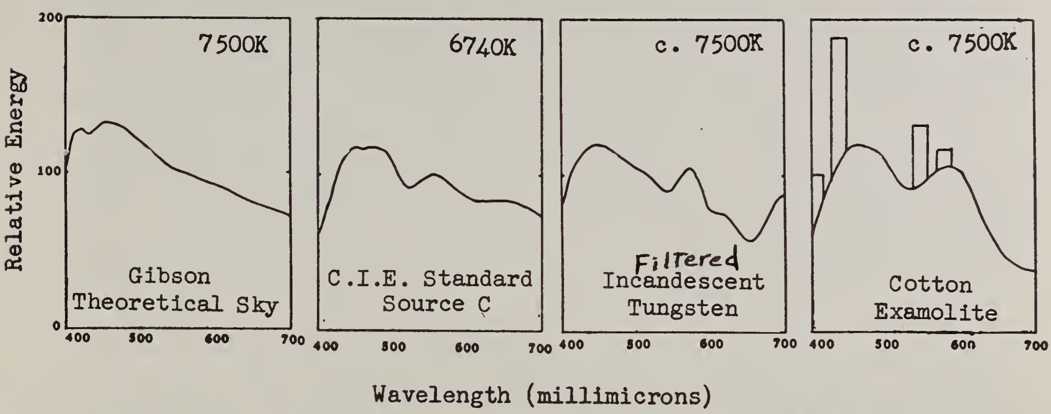


Figure 17. Relative energy curves of theoretical and actual illuminants in the daylight range near to 7500K as recommended for cotton color grading, with the international standard for average daylight—C.I.E. (formerly I.C.I.) illuminant C—shown for comparison and reference.

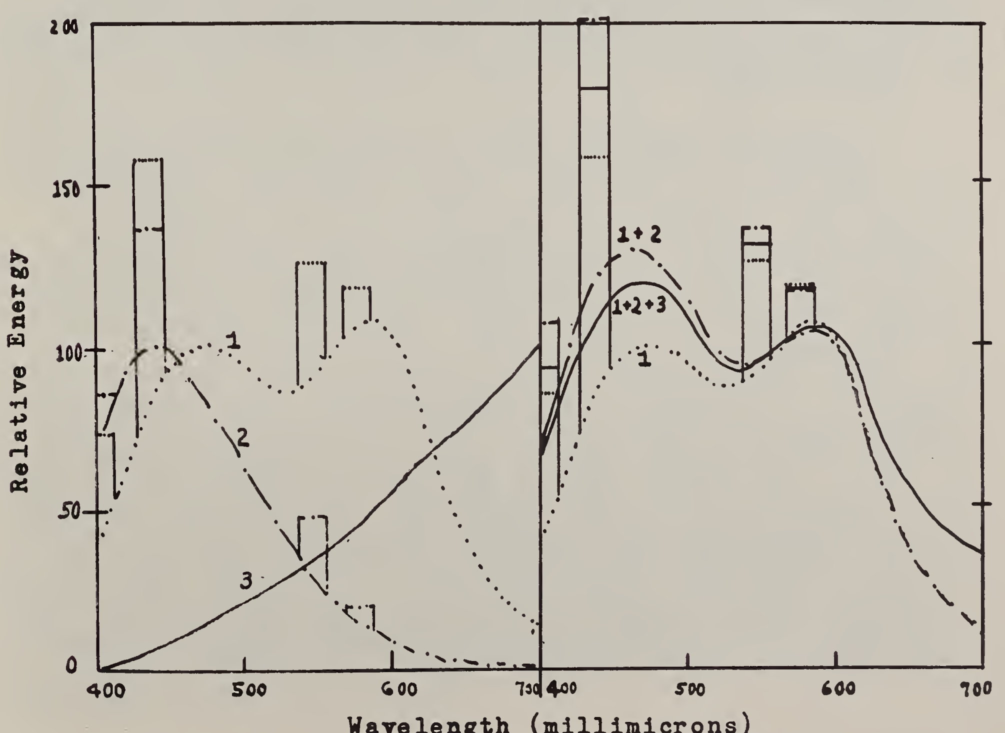


Figure 18. Spectral energy curves of separate and combined lamps used in the cotton examining unit. Curve 1: three 40-watt daylight fluorescent; Curve 2: two 20-watt blue fluorescent; Curve 3: four 25-watt silver-bowl filament lamps.

The next slide (figure 17) shows the relative energy curves of daylight at 7500K and several daylight substitutes. Measured curves of daylight reported by Dr. Abbot of the Smithsonian Institute are used as a basis for the curves marked "Gibson theoretical sky," used as our standard. The C.I.E. curve for Source C, an international standard, is shown for comparison. The curve for filtered incandescent represents the best artificial daylight at 7500K we have been able to attain, and while it does not show as close a reproduction of the daylight curve as we would like, it is almost equally as good as Source C, which is adopted as an international colorimetric standard for average daylight. As for the curve for the cotton Examolite, while it does not appear too close to the 7500K theoretical skylight curve, it is far closer to it than any single fluorescent lamp available today. Compare its curve, for example, to the curve for the daylight fluorescent lamp in the next slide (figure 18) which contains spectral energy curves of the separate and combined lamps used in developing the cotton examining unit. To the daylight curve marked 1 is added the blue of curve marked 2 to make the curve on the right that is marked 1+2. This curve represents the relative spectral energy of the special Examolite fluorescent tubes now manufactured for use in these units. The energy distribution of the 25-watt tungsten filament lamps of the Examolite unit are shown in curve 3. By addition of these lamps the relative amount of red is increased and the blue decreased, as represented in the solid line curve marked 1+2+3. The bars that extend above the curve represent the excess energy of the mercury that activates the fluorescent powders in the fluorescent lamps. These are the "mercury lines."

While it is really the spectral distribution of the illumination that is important in color work, a shorthand description in terms of color temperature often is used to describe the color. At this point it may be well, therefore, to report the most recent information on the color temperature of the new Examolite tube by itself, and the unit complete with regular 25-watt incandescent lamps added, with and without aluminum caps, and the unit complete with the newer incandescent lamps that are designed to last much longer. In a private communication, Mr. Norman Macbeth tells us that they propose to use for this special purpose a gas filled lamp, 40 watts, 130 volts. When operated at 115 volts, as is recommended for the Examolite units, these special incandescent lamps would have a life of over 5,000 hours, with a wattage of 33. C.I.E. (x, y)-data, supplied by Mr. C. W. Jerome of Sylvania's Engineering Laboratories, are the basis for the correlated color temperatures reported in table 4 for these lamps. While the data show that the new incandescent lamp is slightly redder than the present one, an increase in life from less than one to over five thousand hours may offset the importance of this difference. As can be seen, it is really considerably more important to be sure that caps always are used over the incandescent lamps, otherwise the units would really be redder.

Table 4.-Colorimetric data for Examolite fluorescent tube, and for regular and special experimental incandescent lamps.

Lamp, or combination	C.I.E. x	C.I.E. y	Color temperature
Examolite fluorescent tube	0.292	0.314	c.8050K
Examolite tube + regular incandescent lamp, no caps	.307	.323	c.7000K
" " + special " " " "	.310	.324	c.6700K
" " + regular " " with caps	.301	.319	c.7350K
" " + special " " " "	.303	.320	c.7200K

SUMMARY

During the past season the United States Department of Agriculture, in 35 local offices, already has classed over 12.5 million bales of cotton. Visual judgments are the basis for grade and staple determinations of cotton samples: therefore, if classing is to be done uniformly and promptly, the quality and quantity of lighting in a classing room becomes a matter of economic importance.

Natural daylight skylights based on studies that resulted in a "government-type skylight" were used widely from 1914-1937 as a guide by builders and architects designing commercial classing rooms. In the 1930's artificial daylighting studies led to satisfactory units of filtered-incandescent tungsten lighting. These, despite their inefficient use of electric power, were increasingly used by the cotton industry during the 1940's until, by 1949, the cotton man began to lose his long time reluctance to class under anything but daylight.

By 1949-50 many cotton men began to look around for lighting less expensive than the filtered incandescent, and an answer was found by combining in a single unit fluorescent and incandescent lamps to produce a color temperature about 7500K, with a spectral energy distribution as close to that of daylight at 7500K as was possible with these lamps. In the 1950-56 period there has been development and improvement of details, yet the basic specifications remain: Diffuse reflection over a relatively wide area from a wide angle source; color and energy distribution close to that of a moderately overcast sky at 7500K; no less than 60-80 foot-candles on the classing tables. Such substantial achievements have been reached that it is now accepted procedure to supply artificial rather than natural daylighting for classing rooms, and more often than not this is by lighting the entire room. Standard installations employ lighting units set end to end in an even number of rows, the rows on 7-foot centers, with the bottom of units 10 feet from the floor. These may vary from small rooms with two rows of four units each to large rooms with four, six, or even ten or more rows of 10 to 20 units each.

Specifications are provided for lighting units, the color of surrounding conditions, and instructions for maintenance. The importance of spectral quality of lighting and its relation to the product is discussed, and attention called to the corollary that an ideal substitute for daylight is one under which the appearance of samples is the same as under daylight, while a satisfactory substitute is one under which the appearance of samples--their color rendition, or color-difference between samples--is sufficiently duplicated to provide satisfactory grading or inspection. A sound decision as to what is needed involves consideration of the spectral energy distribution of the light source and the spectral reflectance characteristics of the samples, plus a knowledge of inspection and grading practices that apply to the product under study.

While we cannot see any probability of new light sources that will provide in any immediate future practical large-scale lighting with closer spectral energy distribution to daylight than that reported here, nevertheless, it is not impossible that progress in lighting research will one day supply us with such a source. Meanwhile, the answer we have found for cotton will serve equally well for inspection and grading of many other products. When close daylight quality is of prime importance to retain the daylight appearance of any product, the filtered daylight type of lighting may be necessary, but once the psychological adjustment is made toward acceptance of artificial lighting, use of a daylighting substitute may be found less critical for some products than for others. For many products the Examolite type will be satisfactory.

APPENDIX

SPECIFICATIONS FOR LIGHTING UNITS TO BE USED IN COTTON CLASSING ROOMS

TO BE SUPPLIED: Artificial lighting units, each unit to operate with four 40-watt Examolite fluorescent lamps, and four 25-watt incandescent lamps. Lamps to be furnished by bidder. To be in accordance with the following Service Requirements, Specifications and Applicable Conditions.

SERVICE REQUIREMENTS:

The lighting units described herein will be used in the cotton classing laboratories of the Cotton Division, Agricultural Marketing Service, in the classing of cotton samples. For this purpose it is necessary that the units be designed to supply satisfactory amount and color of illuminant over the surface of a classing table when units are placed end to end over the tables, preferably with the bottom of the units 10 feet from the floor, with rows centered 7 feet apart. The units shall be designed to provide an initial illumination on the classing table of no less than 60-80 foot-candles when units are hung as specified, and to provide color and spectral quality as close to that of daylight of a moderately overcast north sky, c.7500K, as is possible in a unit that includes properly designed or especially designed fluorescent lamps. The unit should be suitable for use in a cotton classing room, be easy to maintain in good order and be as light in weight as is practicable.

SPECIFICATIONS:

These units are to be similar or equal to Macbeth Type C4, Cotton Examolite fixtures equipped with Macbeth Examolite fluorescent tubes.

Each unit shall be self contained providing for use of four 40-watt, 48-inch, F40T12-EX fluorescent lamps and four 25-watt* incandescent, inside frosted lamps (A-19 IF). Metal caps shall be supplied for use with the 25-watt incandescent lamps. The unit shall consist of a standard reflector and mixing chamber to combine the light from the several lamps. The four 40-watt Examolite tubes (F40T12-EX) lamps shall be set lengthwise in each unit, and the four 25-watt incandescent lamps shall be set about 11-1/2 inches from the end, 8 inches from the side. The interior shall be finished with a baked white polymerin or other equally good white permanent finish. Ballasts should be rapid start, and of the voltage regulating type. The placement specified is made in order to provide good color mixing. The measurements given are approximate, but should be within a quarter inch tolerance.

Diffusing glass similar or equal to Crista-lite pattern 63-64 (waffle pattern one side, fluted edges on the other side), in panels approximately 2-foot square, shall be used on the bottom to diffuse the light and enclose the unit. The glass must be spectrally neutral (equal in color to Crystalex Plate or Aqua-White). Samples of glass other than Crista-lite, pattern 63-64, must be submitted for color and diffusion tests together with bids. Samples of tubes other than Examolite F40T12-EX, 40-watt size must be submitted with bids. Glass and tubes delivered by successful bidder must be equal to any such samples approved by the U. S. Department of Agriculture when award is made.

The containing box shall be of metal, completely fireproof, approximately 2 feet wide, 4 feet long, not over 14 inches high, with two 3-inch angle brackets on each side of the unit approximately 4 inches from the end. The brackets shall be secured to the unit by one bolt with a nut and lock washer on the inside of the unit to allow for adjustment of the angle of the bracket when hanging. Each bracket shall be drilled with a 5/16" hole for a 1/4" eye bolt.

Each unit shall be designed for operation on 110-120 volt 60 cycle, AC current and wired ready for connection to an electrical plug, with a 6 foot wire. The wire from the electrical connections inside the unit shall be through a 1/2 inch Greenfield connector. Most city electrical codes require a flexible armored cable and nothing smaller than 1/2 inch connectors and cables are used on this size fixture.

---

*Note discussion (pages 26 and 27) of tests now under way of a longer life substitute for these 25-watt incandescent tungsten lamps.

Measurement and Specification of Color Rendition Properties of Light Sources

By DOROTHY NICKERSON

"BEFORE OUR knowledge of the effects of artificial light is satisfactory we must solve the problem of the part played by color." This statement is as true today as it was in 1910, almost fifty years ago, when Herbert E. Ives[1] first discussed color measurements of illuminants before this Society.

The two methods used in his day to measure color of light sources are essentially the same today, although both are now highly standardized: spectroradiometric, in which the relative intensities of the spectra of various light sources are measured wavelength by wavelength, and colorimetric, in which the color of each source is matched by methods of color mixture. The validity of the color matching method is stated in Grassman's law[2] which says that lights of the same color produce identical effects in mixtures, regardless of their spectral composition. Unfortunately for the illuminating engineer, it does not follow that objects seen under light sources of the same color will appear alike in color. The color distortion due to spectral differences in light sources of the same color is one of the problems of color rendition. This problem is fairly simple compared to that which involves also a shift in the color of the light source, for the eye adapts[3] itself to such shifts. Formulas for computed data must take into account the state of an observer's adaptation if they are to predict correctly the color an observer will perceive. In addition to adaptation to the color of the light source, there is adaptation to the background and surrounding conditions under which the observations are made. This all results in a net shift, and it is this net shift we must hope to predict if the illuminating engineer is to have a color rendition rating (whether one — or multi-numbered) that he can use with confidence in a practical situation.

Colorimetry today is a science on so firm a basis that it is doubtful whether many persons realize how much additional information is needed before color rendition of a light source can be predicted accurately. The purpose of this report is to review some of the basic procedures and information that are available and necessary for this work, and to point out what still is lacking, or available in only a very limited way, and what remains to be done.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 9-13, 1957, Atlanta, Ga. AUTHOR: Color Technologist, U. S. Department of Agriculture, Washington, D. C., and Chairman, Subcommittee on Color Rendition, I.E.S. Light Sources Committee. A Transaction of the I.E.S.

What To Use As a Standard

In much color work the first problem is what to use as a standard light source. Back in 1910 Dr. Ives suggested "average daylight," to lie between the extremes of "blue light from the sky" and "the color of low sun," a color that he thought agreed closely with the visible radiation of a black body at 5000K. But even if 5000K were the best choice, obviously one color is not enough, and in 1931 the International Commission on Illumination (CIE) adopted three standard sources, identified as *A*, *B*, and *C*. *A* is intended to be typical of light from a gas-filled incandescent lamp (2854K; *B* is an approximate representation of noon sunlight (4800K); *C* is an approximate representation of average daylight (6740K). For colorimetry of object colors such sources have served an important purpose. But when one wishes to select or compare light sources, even three is not enough. For work involving color grading and color matching the color of CIE Source *C* has been found to be yellower than the color of the daylight used and preferred for this purpose (7400K - 7500K).[4,5]

What is needed is a one-dimensional series with continuous, reasonably smooth spectroradiometric curves that will cover the range from yellowish to bluish whites. For this purpose the one-dimensional series of sources defined by the Planck radiation law has the advantage of having continuous and maximally smooth curves and a convenient and precise definition. But the curves bear little resemblance to those of actual light sources except in the low color temperature range of the incandescent tungsten lamps. Fig 1. In the range of daylight colors use can be made of the one-dimensional series described by Gibson in 1940,[6] known since then as the Abbot-Gibson series. Fig. 2. In this

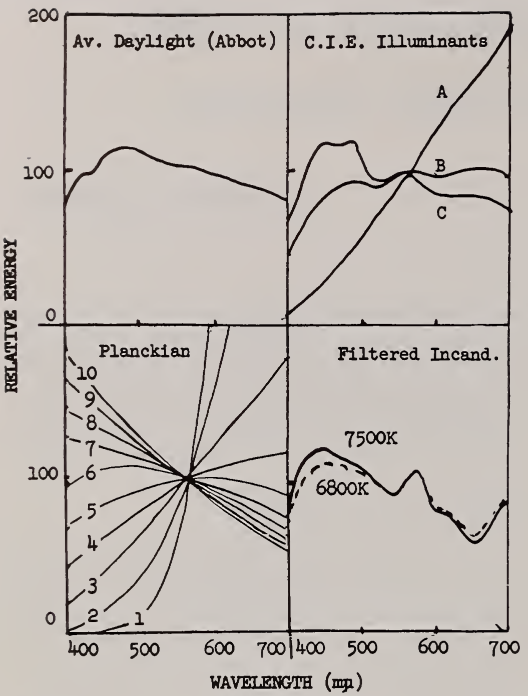


Figure 1. Relative spectral energy distributions for Average Daylight (Abbot); CIE standard Sources *A, B,* and *C;* Planckian black-body radiators, 1 to 10 thousand K, and filtered-incandescent (Corning No. 5900 glass) at 6800 K and 7500 K.

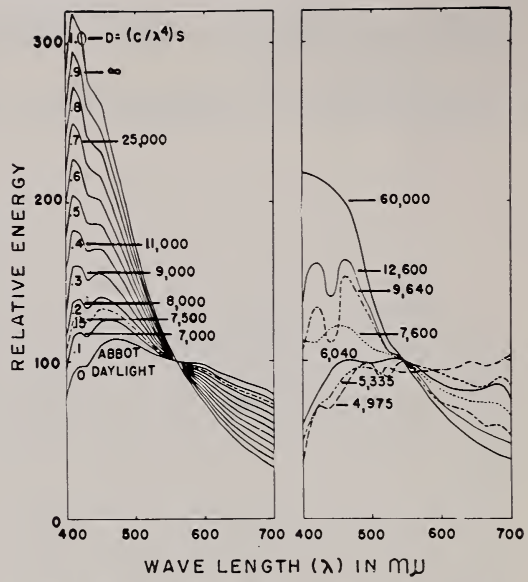


Figure 2. Theoretical daylight curves derived by Gibson from different proportions of Abbot sun-outside-atmosphere and skylight calculated by use of inverse λ^4 scattering relation; and for comparison, curves of daylight measured in 1939 by Taylor and Kerr.

series curves representing sources of desired daylight color may be derived by combining different proportions of Abbot's 1923 measurements of sun-outside-the-atmosphere with the bluest possible skylight, calculated from his data by use of the Rayleigh scattering equation ($1/\lambda^4$). Values of the chromaticity coordinates computed for this series lie on a straight line very close to the Planckian locus. In work involving color rendition of light sources intended to approximate daylight in the 7400 K - 7500 K color temperature range, the Abbot-Gibson curve consisting of 85 per cent Abbot daylight and 15 per cent blue sky has been particularly useful. The curve for Abbot daylight alone computes to a color that plots on the Planckian locus just above 6000 K, with 10 per cent blue sky it is about 7000 K, with 20 per cent about 8000 K, and with 30 per cent about 9000 K. Because these data are of considerable current use (and are not available in detail except in a 1940 mimeographed report[7] now out of print) they are given in Table I. By interpolation the approximate spectral energy distribution for any measured color temperature of the sky may be derived.

In writing specifications or in performing instrumental colorimetry, the standards discussed are very useful. But when it is necessary to make observations it becomes dishearteningly clear that most of these light sources are either completely theoretical, or quite impractical to use for illuminating objects that are to be observed. Daylight is used most often in making observations of the color of objects, and the "daylight color" certainly is the one most often wanted. But while approximations can be made, no real colorimetric precision is possible for experiments made under a light source that cannot be specified accurately for the duration of the experiment. As we continue to compile colorimetric information it becomes increasingly evident that to solve some of our color rendition problems we need observations made under very precisely measured conditions of illumination.

The three CIE standards include a gas-filled lamp operating at a color temperature of 2845 K (1948), and this lamp used with double liquid filters. Use of these liquid filters is possible in instrumentation, but it is not very convenient. For work involving filters, the liquid filters often are supplanted by Corning's glass filter No. 5900, which is designed to convert the color of incandescent lamps to that of daylight with as close a match to

TABLE I — Abbot-Gibson Data for Spectral Energy Distributions of Skylight.

Wave-length mμ	Day-light[1] S_o	Blue Sky[2] S_b	Blue Sky + Average Daylight in Varying Proportions										
			.05+.95[3]	.1+.9	.15+.85	.2+.8	.3+.7	.4+.6	.5+.5	.6+.4	.7+.3	.8+.2	.9+.1
380	62.0	292.4	73.5	85.0	96.6	108.1	131.1	154.2	177.2	200.2	223.3	246.3	269.4
90	63.9	271.6	74.3	84.7	95.1	105.4	126.2	147.0	167.7	188.5	209.3	230.1	250.9
400	73.4	282.0	83.8	94.3	104.7	115.1	136.0	156.8	177.7	198.5	219.4	240.3	261.1
10	91.5	318.4	102.8	114.2	125.5	136.9	159.6	182.3	205.0	227.7	250.4	273.1	295.8
20	97.0	306.6	107.5	118.0	128.4	138.9	159.9	180.8	201.8	222.7	243.7	264.7	285.6
30	96.9	278.7	105.8	115.1	124.2	133.3	151.4	169.6	187.8	206.0	224.2	242.4	260.6
40	102.9	270.0	111.3	119.6	128.0	136.3	153.0	169.7	186.4	203.2	219.9	236.6	253.3
450	109.6	262.8	117.4	124.9	132.6	140.2	155.6	170.9	186.2	201.6	216.9	232.2	248.0
60	112.0	246.0	118.5	125.4	132.1	138.8	152.2	165.6	179.0	192.4	205.8	219.2	232.6
70	113.5	228.8	119.2	125.0	130.8	136.6	148.1	159.6	171.1	182.6	194.2	205.7	217.2
80	113.6	210.5	118.5	123.3	128.1	133.0	142.7	152.3	162.0	171.7	181.4	191.1	200.8
90	112.1	191.2	116.0	120.0	124.0	127.9	135.8	143.8	151.7	159.6	167.5	175.4	183.3
500	110.7	174.2	114.0	117.0	120.2	123.4	129.8	136.1	142.4	148.8	155.1	161.5	167.8
10	108.5	157.7	110.9	113.4	115.9	118.4	123.3	128.2	133.1	138.0	143.0	147.9	152.8
20	105.9	142.4	107.7	109.6	111.4	113.2	116.9	120.5	124.2	127.8	131.5	135.1	138.8
30	103.4	128.9	104.7	106.0	107.2	108.5	111.0	113.6	116.1	118.7	121.2	123.8	126.3
40	101.7	117.6	102.6	103.3	104.1	104.9	106.5	108.1	109.7	111.3	112.8	114.4	116.0
550	100.9	108.4	101.1	101.6	102.0	102.4	103.2	103.9	104.7	105.4	106.2	106.9	107.7
60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
70	99.1	92.3	98.9	98.4	98.1	97.8	97.1	96.4	95.7	95.0	94.4	93.7	93.0
80	98.6	85.7	98.1	97.3	96.7	96.0	94.7	93.4	92.1	90.8	89.6	88.3	87.0
90	98.3	79.8	97.4	96.4	95.5	94.6	92.7	90.9	89.0	87.2	85.3	83.5	81.6
600	97.4	73.9	96.2	95.0	93.9	92.7	90.4	88.0	85.7	83.3	81.0	78.6	76.3
10	95.2	67.6	93.8	92.4	91.1	89.7	86.9	84.2	81.4	78.6	75.9	73.1	70.4
20	93.1	62.0	91.7	90.0	88.4	86.9	83.8	80.6	77.5	74.4	71.3	68.2	65.1
30	91.0	56.8	89.2	87.6	85.9	84.2	80.7	77.3	73.9	70.5	67.1	63.6	60.2
40	89.3	52.4	87.4	85.6	83.8	81.9	78.2	74.5	70.8	67.1	63.4	59.7	56.0
650	87.5	48.2	85.7	83.6	81.6	79.6	75.7	71.8	67.8	63.9	60.0	56.1	52.1
60	86.0	44.6	84.0	81.9	79.8	77.7	73.6	69.4	65.3	61.1	57.0	52.9	48.7
70	84.6	41.3	82.5	80.3	78.1	75.9	71.6	67.3	62.9	58.6	54.3	49.9	45.6
80	83.3	38.3	80.9	78.8	76.6	74.3	69.8	65.3	60.8	56.3	51.8	47.3	42.8
90	81.4	35.3	79.2	76.8	74.5	72.2	67.6	63.0	58.4	53.8	49.1	44.5	39.9
700	79.1	32.4	76.8	74.4	72.1	69.8	65.1	60.4	55.8	51.1	46.4	41.7	37.1
10	76.8	29.7	74.4	72.1	69.7	67.4	62.7	58.0	53.3	48.6	43.8	39.1	34.4
20	74.4	27.2	72.0	69.7	67.3	65.0	60.2	55.5	50.8	46.1	41.4	36.7	32.0
30	72.2	25.0	69.8	67.5	65.1	62.8	58.0	53.3	48.6	43.9	39.2	34.4	29.7
40	70.2	23.0	67.8	65.5	63.1	60.8	56.1	51.3	46.6	41.9	37.2	32.5	27.8
750	68.2	21.2	65.9	63.5	61.2	58.8	54.1	49.4	44.7	40.0	35.3	30.6	25.9
60	66.1	19.5	63.8	61.4	59.1	56.8	52.1	47.5	42.8	38.1	33.5	28.8	24.2
70	63.9	17.9	61.6	59.3	57.0	54.7	50.1	45.5	41.9	36.3	31.7	27.1	22.5
380–770 x	.3204	.2319	.3139	.3076	.3016	.2959	.2854	.2757	.2669	.2588	.2513	.2444	.2379
380–770 y	.3301	.2318	.3228	.3158	.3092	.3029	.2912	.2804	.2706	.2616	.2533	.2456	.2384
400–700 x	.3204	.2320	.3138	.3075	.3016	.2959	.2854						
400–700 y	.3304	.2322	.3231	.3161	.3095	.3032	.2915						
c.C.T.	6100K	α	6500K	7000K	7400K	8000K	9300K	11,000K	14,000K	18,000K	25,000K	47,000K	60,000K

[1] S_o, Daylight-Outside-Atmosphere (Abbot, 1923).

[2] S_b, $(C/\lambda^4)\ S_o$.

[3] Data are from 1939 K. S. Gibson tables to D. N.

the spectral energy of daylight as can be obtained by use of a glass filter. In this country this filter is used in many instruments, and when the source-filter color temperature matches that of *C*, often it is identified as if it were equivalent to *C*. Used in varying thicknesses this glass can provide a series of colors that vary all the way from the color of the unfiltered light source to that of light of limit-blue-sky. In large size, this same filter is used in lamps to provide a standard source for making color observations.

One of the first questions before your subcommittee* on Color Rendition[8] was what source should be used as a standard against which to check the color rendition of the test source. Three one-dimensional series of sources were considered:

A. The sources defined by the Planck radiation law,

B. Series A to 3000K, and for higher correlated color temperatures an incandescent lamp at 3000K with filters of Corning Daylite glass,

C. Series A to 6000K, and the Abbot-Gibson series from 6000K to limit-blue-sky.

Only one of these was possible for use in practical tests, therefore it was decided that series B would be used in validation, and series C for a formal standard. The very necessity for this division into

*Subcommittee on Color Rendition, IES Light Sources Committee. Members, past and present: A. C. Barr, E. W. Beggs, C. N. Clark, C. W. Jerome, D. B. Judd, Norman Macbeth, Dorothy Nickerson, Ch., C. R. Stilwell, C. E. Swanson, Luke Thorington, A. W. Weeks; Advisors: R. M. Evans, Günter Wyszecki. The scope is to establish a method of measuring and specifying the color rendition properties of light sources, with priority given to fluorescent lamps.

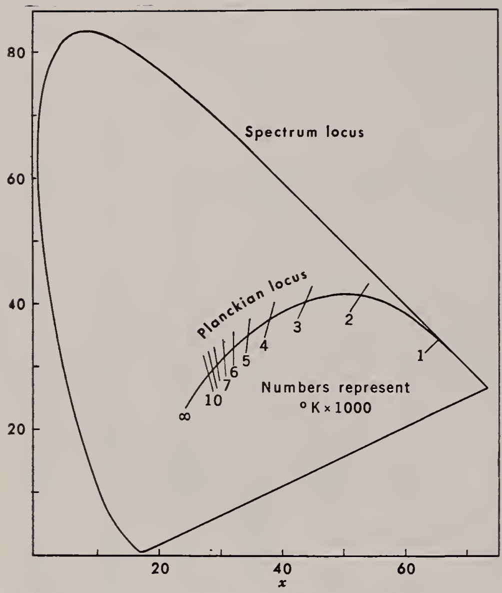


Figure 3. CIE chromaticity diagram in its most widely used (x, y)-form.

a practical and a formal standard indicates how very real the problem of a standard is. But it is the best we can do for the moment.

How Shall Colorimetric Results Be Expressed?

In colorimetry three things are necessary to specify the color of an object: a light source, an object to reflect or transmit the light from that source, and an observer to see it. Since 1931 a considerable amount of careful colorimetric data, much of it based on spectrophotometric measurements, has been compiled in terms that are similar all over the world, wherever modern colorimetry is practiced. This is possible because of the adoption by the CIE of specifications for a standard observer for colorimetry as well as for standard light sources. So often are these two of the necessary three variables kept constant in practice that it has been possible to assemble sufficient data to make great progress not only in specifying color but in correlating the differences in specifications with the size of the color difference they represent.

Tables of data defining the CIE Standard Observer and CIE Standard Light Sources *A, B,* and *C* will be found in the *IES Lighting Handbook* together with an example that illustrates the mechanics of computing the color of a particular sample. For more details see chapters on Psychophysics of Color and Quantitative Data and Methods for Colorimetry in reference 3. Refer also to a paper on this program by Judd.[9]

A CIE color specification consists of three numbers, either the tristimulus values X, Y, and Z that are required to establish a match with the sample color; or the tristimulus value, Y, which is a measure of luminance, and x, y, two of the three chromaticity coordinates (ratios of the X, Y, Z numbers to their total) that by custom are used as coordinates for the form of the CIE chromaticity diagram illustrated in Fig. 3, the form with which we are most familiar. One very useful fact about this diagram is that additive mixtures of any two colors lie along the straight line connecting the two end colors.

The spectrum locus, the Planckian locus, in fact the locus of any light source is fixed on this diagram. Kelly[10] has worked out a color-name designation for lights in which the name limits are expresed by lines drawn on such a diagram. These instances show a unique use for this diagram. It may be noted that they require only two variables, a light source and an observer. The question, "What is white?" becomes important, and for an anchor point, the color representing an equal energy spectrum is used. It plots at the center of the diagram, $x = 0.3333$, $y = 0.3333$, about 5500 K.

The minute that an object enters the picture, a choice of a single light source must be made in order for the color of that object to be specified and plotted on the diagram. In this country it is usual for the CIE specification of object colors to refer to colors perceived by the "standard observer" in "average daylight."

Thus the point representing CIE Source *C* becomes the color center of the diagram, the center to which the colors of all objects seen under that light source are related. A great deal of work has been done for the diagram in which *C* is the center that is not available for diagrams in which other sources are the focal point. There is a psychological concept of equally perceptible differences of object colors in which color differences may equal each other regardless of source. This makes it possible to develop scales of hue, lightness, and saturation such as has been done in developing the concept of the Munsell scales of hue, value, and chroma. A distinction should be made between the concept and its representation, for when the concept is illustrated by samples, the samples must be made for a single set of conditions. When Munsell papers were made to represent these scales, the work was done in daylight.

One of the aims of the extensive studies on the spacing of the Munsell system[11] by a subcommittee of the Optical Society of America was to express in terms of the CIE notation for Source *C* enough

surface colors corresponding to their recommendations to define the system adequately. This means that the observations were made in daylight, or under a light source intended to be an equivalent to daylight, and that the results were specified in relation to Source *C*. The loci for constant Munsell hue and chroma for Source *C* are illustrated in Fig. 4 on a CIE chromaticity diagram. Hue and chroma loci for other values show a regular displacement, value by value, for hue and chroma. Thus two important facts become clear: even for daylight conditions and equal luminance, equal distances on the *(x, y)*-diagram do not correspond to colors perceived as equally different, and, for colors that vary in lightness, the same point on the diagram can represent colors that may differ considerably from each other both in hue and in saturation.

The first fact, while it is not always kept in mind, is widely known. For years there has been a search by various workers to find some sort of diagram that would represent more uniform spacing. In a 1947 paper[12] the writer assembled 15 different diagrams in this field, from Judd's first UCS diagram (1935), and covering work by MacAdam, Breckenridge and Schaub, Farnsworth, Scofield-Judd-Hunter, Adams, Moon and Spencer, Saunderson and Milner. There have been others since.[13]

The second fact has not had the attention it deserves, although as a practical matter it is just as important. The most important work that has taken into consideration this change in chromaticness (hue and chroma) for a constant point on the chromaticity diagram (constant dominant wavelength and purity) with change in lightness (or Y value), is that of Hunter in his *(a, b)*-diagram and that of Adams in his Chromatic-Value Diagram. The diagram that comes closest to converting CIE data regardless of the value of Y, to constant chromaticness is one reported by Nickerson, Judd, and Wyszecki[14] in 1955. This diagram indicates that it is possible to make a close approximation to conversion of CIE data to constant chromaticness as well as to constant chromaticity, but the method is not yet simple enough for practical use, nor is the hue spacing as good as we would like.

While all of this work goes on to find a uniform color space, the *(x, y)*-diagram is still most used. Used with a series of diagrams similar to the one in Fig. 4, but for a range of value levels from dark to light, or used with data based on the MacAdam ellipses of constant size of color difference, it is possible to develop a great deal of information regarding the size of color differences. For daylight conditions we do not yet have all the answers (even now a committee of the Optical Society of

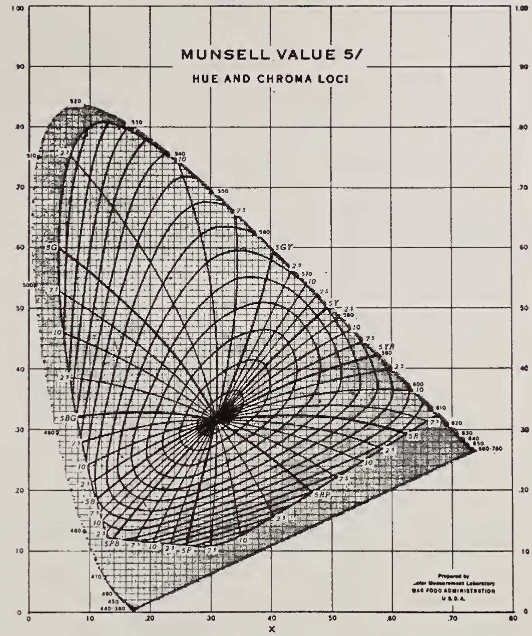


Figure 4. Loci of Munsell constant-hue and constant-chroma for value 5/ in CIE (x, y)-coordinates for Source *C*.

America is working on a long-term project regarding uniform color spacing), but we do have enough to make work in colorimetry practical and useful. Munsell notations, directly obtained or converted from CIE specifications, provide a simple and practical method of working with uniform color scales.

If our color rendition problems could all concern the appearance of samples under light sources that differ in spectral distribution but are all a match in color for Source *C*, we might be able to solve them in a reasonably straightforward manner. For Source *C* we have a Munsell network worked out, so that a method is available for obtaining color specifications for the appearance of a sample under any number of light sources, just so long as they have the color of *C*. No problem of adaptation to the color of the light source would be involved since the adaptation would be the same for each source. There would, of course, be the problem of adaptation to any change in background color, but for the moment let us assume that this is neutral and held constant.

An example will serve to illustrate what is meant. For several years a subcommittee of this society has been working on the problem of color rendition of light sources, and as test objects they have included 18 Munsell 6/ value papers selected by Barr, Clark, and Hessler[15] for studies reported in 1952. Among

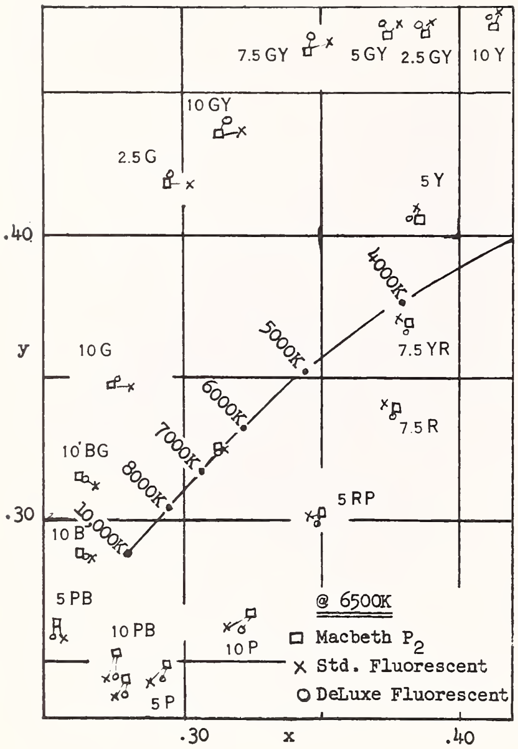


Figure 5. Color rendition of light sources: 18 Munsell samples for three light sources that are the same daylight color (6500K). This illustrates the color difference in samples caused by a difference in spectral distribution of light source.

the light sources used in the subcommittee's tests are three that are color matched in the daylight range. The spectral reflectances of the 18 samples were used to compute chromaticity coordinates according to the CIE Standard Observer for the spectroradiometric distributions of each of the three test sources. The light sources used were an incandescent lamp with Macbeth P_2 filter (Corning No. 5900), a standard fluorescent lamp, and a deluxe fluorescent lamp, all specially made to color-match at 6500K. The results are plotted on a CIE (x, y)-diagram in Fig. 5.

Since the samples are the same, and the color of the light sources is the same, the differences in color are due to differences in the spectroradiometric curves of the three light sources. The points representing the color of the light sources fall close to the Planckian locus between the points marked 6000K and 7000K. For purposes of illustration let us assume they are a close match for Source C so that we can read off the Munsell notations from the standard diagram for 6/ value (similar to the 5/ value diagram illustrated in Fig. 4). (Actually the 6500K light sources are slightly yellower than C, about 0.25 chroma steps on the C diagram, so that the notations will not be as accurate as if the three light sources were precisely at the C point.)

The resulting color differences are listed in Table II in terms of hue, value, and chroma differences, ΔE_N (a number representing the total color difference),[16] and an arbitrary number representing the distance on the (x, y)-diagram between the point

TABLE II — Color Differences Between Color Rendition of 18 Samples Under a Standard Lamp (Incandescent-Plus-Macbeth P_2 Filter) and Under Two Fluorescent Lamps, Deluxe and Standard, All Three Lamps Color-Matched at 6500K.

Color Sample Munsell Notation	No.	Δ Hue Deluxe	Δ Hue Std.	Δ Value Deluxe	Δ Value Std.	Δ Chroma Deluxe	Δ Chroma Std.	ΔE_N Deluxe	ΔE_N Std.	Deluxe (x, y)-distance	Std. (x, y)-distance
5 Y 6/4	1	+0.5	+1.0	0	0	0	+0.1	0.9	2.1	15	35
10 Y 6/6	2	+0.5	+0.5	0	+0.1	+0.1	+0.2	1.8	2.7	30	40
2.5 GY 6/6	3	+0.5	0	+0.1	+0.1	+0.1	+0.2	2.3	1.2	30	40
5 GY 6/8	4	+0.3	−0.2	0	0	+0.2	+0.2	1.4	1.2	40	45
7.5 GY 6/6	5	0	−0.5	0	0	+0.2	0	0.6	1.5	40	60
10 GY 6/6	6	−0.3	−0.9	0	0	+0.2	−0.2	1.4	3.1	45	65
2.5 G 6/6	7	−0.3	−1.2	0	−0.1	+0.1	−0.6	1.1	5.8	20	70
10 G 6/4	8	−0.6	−0.9	0	0	0	−0.5	1.0	2.9	20	55
10 BG 6/4	9	0	+1.0	0	−0.1	−0.1	−0.4	0.3	3.2	15	45
10 B 6/4	10	+0.5	+1.5	0	0	−0.1	−0.4	1.0	2.7	10	35
5 PB 6/8	11	+1.0	+1.5	0	0	−0.2	+0.2	2.8	3.9	30	40
10 PB 6/8	12	+0.5	0	0	0	+0.9	+1.0	4.0	3.0	55	65
2.5 P 6/8	13	0	−0.5	0	0	+0.5	+0.5	1.5	3.1	40	50
5 P 6/8	14	−0.3	−1.0	0	0	+0.5	+0.5	2.4	4.5	40	60
10 P 6/8	15	−0.5	−0.5	0	−0.1	+0.4	0	2.6	4.8	40	75
5 RP 6/6	16	−1.0	−1.0	0	−0.1	+0.1	−0.3	2.3	3.5	25	35
7.5 R 6/4	17	−0.5	+2.0	0	0	0	−0.4	0.8	4.4	15	35
7.5 YR 6/4	18	−0.5	+1.5	0	0	0	−0.1	0.7	2.4	15	25
Avg Diff.		0.4	0.9	0.0	0.03	0.2	0.3	1.6	3.1	29	48

[1] ΔE_N = 1936 Nickerson "Index of Fading" = $(C/5)(2\Delta H) + 6\Delta V + 3\Delta C$.
This is a single number measure for color difference that is based on equivalence (for average viewing conditions) of 3 hue steps (at /5 chroma) to 1 value step, to 2 chroma steps. For special conditions the weighting for value may be varied.
[2] Arbitrary units.

representing each sample under the standard lamp and the points under the deluxe and standard fluorescent lamp. While the color differences are small (because at this high color temperature the spectral differences between the lamps are at a minimum), it is clear that the average color rendition of these samples for the deluxe fluorescent lamp is closer to that of the standard (incandescent-plus-filter) lamp than is the average color rendition under the standard fluorescent lamp. This is true whether we compare the hue, value, or chroma differences, the total differences, or the differences measured by distance on the (x, y)-diagram. If we had a diagram of truly uniform spacing, we should expect, if all necessary factors are taken into consideration, that the distances measured on it should correlate well with the perceived differences in chromaticness. Meanwhile, we use the Munsell notation, as read from the diagrams, to give us the best and most practical approximation we know how to get.

What can be done when light sources are not the color of daylight?

For the same 18 samples your subcommittee has worked with two other groups of light sources, each containing three lamps. One group was color-matched at 3000K, and the other at 4500K. In each group there is a standard lamp (incandescent for 3000K, filtered-incandescent for 4500K) and two fluorescent lamps, standard and deluxe. Computations and observations have been made for all conditions. Relative energy curves for the three groups of light sources are shown in Fig. 6. (This paper is not intended as a report of this work, but as a means of clarifying for others interested in problems of color rendition some of the problems that face the subcommittee.)

If we were able to transfer the Munsell network for Source C to the standard sources at 3000K and at 4500K so that it would provide the same spacing of colors that we have in daylight, we could then read off the colors in terms of their daylight appearance, and compare the color rendition of samples under one light source with that under another. This includes the problem of adaptation. But we have no way of doing this yet. The work of Helson[17,18] and Burnham[19,20] and their co-workers is providing a beginning toward this, but unfortunately it still looks as if we are a long way from being able to transfer the Munsell network to light sources of other chromaticities.

How then is it possible to put together the data for these different levels of color so that the internal results for each set may be compared with the internal results for the others? The matter is put this way in order still to avoid the problem of adaptation, a problem that must be faced when results are compared under light sources that differ in chromaticity.

Colorimetric results for the 18 samples, under

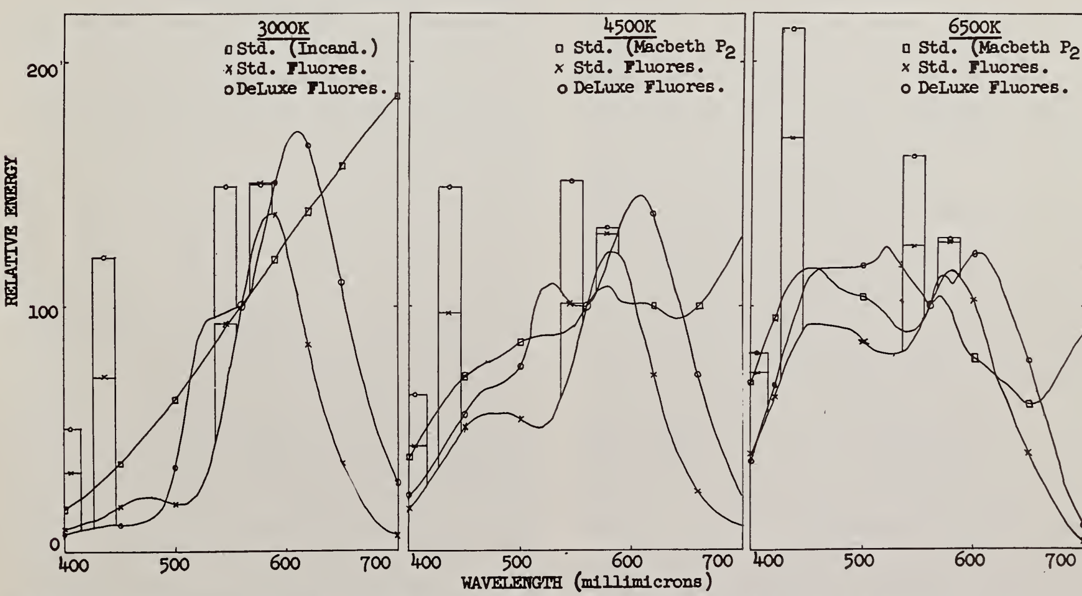


Figure 6. Relative spectral energy curves, adjusted to 100 at 560 mμ, for triads of lamps at 3000K, 4500K, and 6500K. In each group the squares refer to the standard lamp, crosses to standard fluorescent lamps; open circles to deluxe lamps.

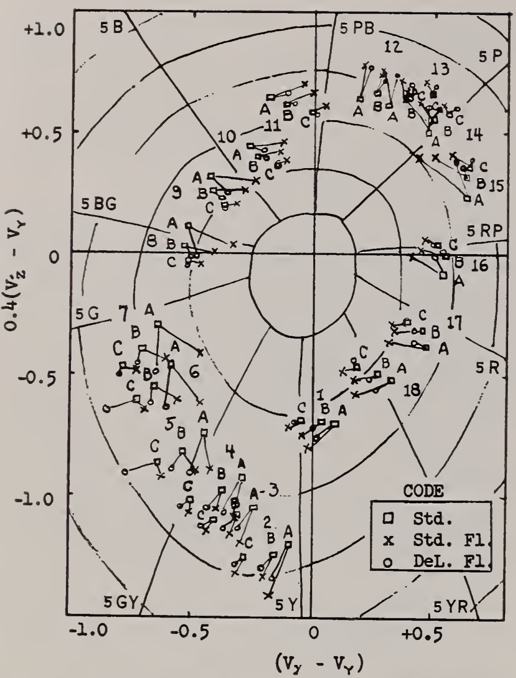


Figure 7. 18 Munsell samples, each calculated for 3 triads of light sources. These are plotted against a Munsell renotation network of hue and chroma on the Adams' Chromatic-Value Diagram to illustrate the relative size and direction of color change caused by change in light source. Code: Group A, at 3000K; Group B, at 4500K; Group C, at 6500K.

three triads of light sources, have been computed and plotted on as many types of diagrams as seemed promising. The only one on which all of the data could be assembled at one time so that some sort of comparison could be made between the results for each group, is the Adams' Chromatic-Value Diagram. All of these data are shown in Fig. 7, a Munsell Renotation Diagram for 6/ (the value of the samples used as test objects), superimposed on the Adams' diagram. From the data on this diagram it is evident that the color differences under the group of lamps at 3000K are much larger than those under 4500K, and that these in turn are larger than those under 6500K. The relative amount, and the direction of change within groups can be compared for similarities and differences. We have no way at present of knowing how the groups should be displaced to account for adaptation to the several light sources, although a correction for adaptation is made by the very use of the vonKries type of transformation that places the light source always at (0,0) on the Adams' diagram. While it does not agree with all the facts

TABLE III — Color Difference (ΔE_N) on 18 Samples.

Color Sample		ΔE_N between					
		3000K Std vs		4500K Std vs		6500K Std vs	
		Fluorescent					
Munsell Notation	No.	Deluxe	Std.	Deluxe	Std.	Deluxe	Std.
5 Y 6/4	1	4.0	6.7	1.8	4.4	2.3	4.3
10 Y 6/6	2	7.4	8.8	3.3	4.5	2.4	3.3
2.5 GY 6/6	3	5.9	4.9	3.1	2.1	4.0	2.9
5 GY 6/8	4	4.7	5.0	2.4	3.6	2.3	0.9
7.5 GY 6/6	5	6.1	7.8	2.1	3.3	3.0	3.1
10 GY 6/6	6	6.9	8.9	3.6	6.0	4.6	2.9
2.5 G 6/6	7	6.6	11.8	3.0	5.4	1.9	3.1
10 G 6/4	8	10.4	10.0	3.5	4.8	0.8	2.0
10 BG 6/4	9	3.7	11.6	3.1	7.7	1.1	3.6
10 B 6/4	10	4.5	10.0	2.3	6.3	0.3	1.8
5 PB 6/8	11	4.6	9.0	1.4	6.9	1.3	3.4
10 PB 6/8	12	5.1	6.4	3.0	3.0	2.2	0.9
2.5 P 6/8	13	9.3	9.9	2.1	6.0	2.6	4.3
5 P 6/8	14	10.0	15.9	3.9	9.6	0.6	5.2
10 P 6/8	15	14.6	22.8	4.2	12.5	2.1	6.4
5 RP 6/6	16	7.4	11.2	0.6	4.1	1.2	3.3
7.5 R 6/4	17	3.2	11.0	2.9	8.0	0	0
7.5 YR 6/4	18	3.7	8.9	1.8	6.4	0.6	1.1
Average		6.6	10.0	2.8	5.8	1.9	3.0

that eventually must be taken into consideration, nevertheless for computing *differences* we can make use of the Munsell network on this Adams diagram and read off the notations and calculate them in terms of ΔE_N. This has been done for the group of lamps at each color level. The results, shown in Table III, provide a preliminary sort of color rendition rating for the several light sources by the size of the average color difference for the 18 samples seen under them. (The Source *C* data for ΔE_N in Table III differ from the data for ΔE_N in Table II because there is a difference in the standard lamp to which each is compared.)

This suggested use of the Adams' diagram is not intended as a final proposal, but it does point the way to the sort of thing that it should be possible some day to do with accuracy and with precision. Some way must be found to pull all the data together, preferably to show their relation to the separate factors of Munsell hue, value, and chroma, as well as to the size of the total color difference.

The Adams' diagram, for those who are not familiar with it, requires the use of CIE data for *X, Y, Z*. After adjustment so that $X = Y = Z$ for the light source (essentially an adjustment for adaptation), the data are then converted to V_x, V_y, V_z by use of the Munsell value scale. $(V_x - V_y)$ is plotted against $0.4(V_z - V_y)$. Since *Y* carries all of the luminance, after its subtraction from the *X* and *Z* factors only the chromatic factors are left, and they are plotted against each other, the neutral series at the center (0,0), reds in the direction of $+(V_x - V_y)$, greens in the $-$ direction, purple-blues in the direction of $+(V_z - V_y)$, and yellows in the $-$ direction. The calculations are simple to make, they require use of a table of the Munsell Value function and *X, Y, Z* data for the samples.

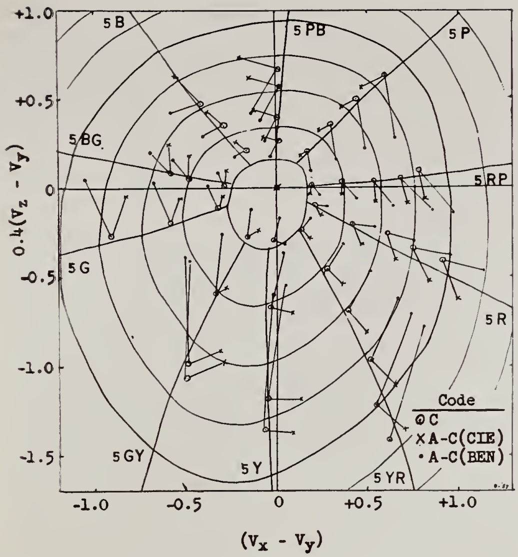


Figure 8. A series of Munsell samples (10 hues on 6/ value) as they plot on the Adams' diagram for Source *C* (circles), the same samples for Source *A* (crosses), and as calculated by the Judd prediction formula based on the Burnham data (solid points) for equal-appearing colors for Source *C* adaptation based on measurements for Source *A*. This illustrates, after conversion to the Adams' diagram, the size and direction of the color changes predicted by the Burnham studies versus those predicted on a basis of CIE primaries.

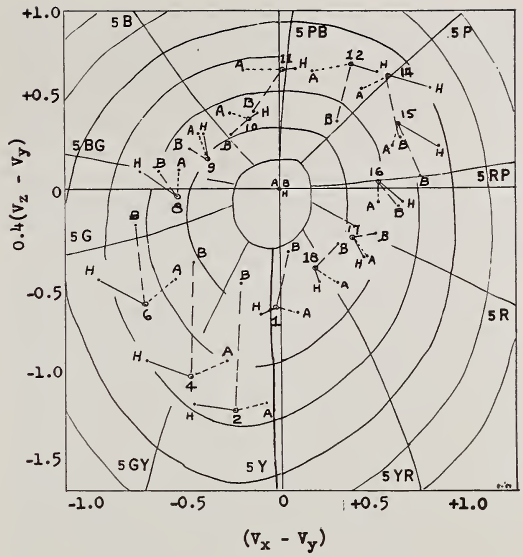


Figure 9. The effect of chromatic adaptation under Source *A* that is predicted in terms of Source *C* by formulas based on three sets of primaries, numbered 1 to 3 in the text, is shown on an Adams' Chromatic-Value Diagram: A (CIE) refers to (1), H (Helson) to (2), and B (Burnham) to (3). Circled points represent the *C* color of each sample; Munsell notations for the sample numbers are listed in Table II; N 6/ is at the center by all three formulas.

This same diagram allows one to study the Helson and Burnham results. In fact, it is possible in paired diagrams to plot the calculated and the observed data, and then compare them to see the extent of the differences between the two methods. This has been done for the Helson data since CIE data already were available[21] for the samples and light sources used in his most recent study.[18] Unfortunately, the scatter of the observations is so great that it is hard to find the pattern, but the data serve for reference involving other observational data. The Burnham results, by use of the prediction formula reported[20] for equal-appearing color with adaptation to Source *C* when the Source *A* color is known, were worked out for the basic series of 420 Munsell samples. However, the illuminants used in the Burnham-Evans-Newhall work were not precisely *A* and *C*, in fact Burnham's approximation to *C* was different enough so that N 6/, instead of reading 0 chroma as it does under CIE_C, read almost /2 chroma. Since Judd had worked out some months ago reversible formulas based on the Burnham-Evans-Newhall data that could be applied to light sources other than the precise ones used in making the observations, this Judd *A*-to-*C* formula was applied to Munsell 6 value samples. The results for this formula and for the CIE *A* to *C* conversion are shown in Figure 8, with lines connecting each of the results to the *C* color for each sample.

The communication in which Dr. Judd supplied the formula used for the foregoing conversion also provided similar formulas for two additional sets of primaries, making three in all:

(1) CIE primaries (used in the Adams' chromatic value space).

(2) Judd-Wyszecki primaries (which fit the Helson data and some of the MacAdam[22] data on chromatic adaptation).

(3) Brewer primaries (which fit the Burnham, Evans, Newhall data on chromatic adaptation).

Primaries	From *A* to C	From C to *A*
(1)	$X'=0.892X$ $Y'=1.000Y$ $Z'=3.321Z$	$X'=1.121X$ $Y'=1.000Y$ $Z'=0.301Z$
(2)	$X'=1.155X-0.457Y+0.476Z$ $Y'=1.000Y$ $Z'=3.321Z$	$X'=0.866X+0.396Y-0.124Z$ $Y'=1.000Y$ $Z'=0.301Z$
(3)	$X'=1.092X-0.272Y+0.149Z$ $Y'=1.000Y$ $Z'=-0.284X+0.839Y+1.835Z$	$X'=0.896X+0.306Y-0.073Z$ $Y'=1.000Y$ $Z'=0.139X-0.410Y+0.534Z$

Since these three formulas cover much of the work for which there is any considerable systematic

body of observational data, all three have been applied to converting CIE A data to terms of C for 14 of the samples used in the subcommittee work, plus N 6/. The results indicate the effect of chromatic adaptation under CIE Source A compared to CIE Source C that is predicted on the basis of the three sets of primaries named. In Figure 9 lines connect to the C point for each sample, the points that represent the color of each sample under A. These lines represent predicted color shifts.

As can be seen, there seems to be considerable difference in the predictions, depending upon the primaries used, the choice of primaries perhaps depending in turn on the conditions of the experiment. These predicted color shifts are much larger than the color distortions shown in Figure 7 where they are due to changes caused only by spectral differences among commonly used light sources. We know that adaptation results in a shift in the color of many objects, and while we know from a study of this last figure that the formulas here seem to provide results that differ considerably, they do make us hopeful that before too long we shall be able to find a formula that for specified background conditions will predict correctly the daylight color of objects that we see in our living rooms at night under incandescent light. Once a formula will provide this, then ways can be worked out to apply it to illuminants other than A and C. At present, we still do not know just what formula to use in order to calculate the daylight color of objects seen under tungsten — or other — light sources.

What Is Needed?

Eventually we must have a network representing uniform spacing that can be applied to whatever light source is of interest, one in which the relation between calculated and observed data is satisfactory for standardized conditions. We need a designation (such as the CIE) that can be calculated from measured data, and a designation (such as the Munsell) that will represent the appearance of a color, with some method by which these two can be converted from one to the other for any light source, sample, observer, and background.

As a practical matter we need to have computations for the basic Munsell series for whatever light sources are of most current interest, and we need to have these based on careful spectroradiometric measurements that will represent the average of lamps that are, or can be made available for observation. The eye sees very small differences, and is very critical. It is therefore important that observations and calculations be based on the same conditions, not just *nearly* the same. More work of the sort being done by Helson and Burnham is needed, not isolated studies, but studies precise and well planned, with all of the basic data and materials easily available for others to use (as has been the case with these workers). On the basis of such observations a Judd or a Brewer may find for us equations that will apply to the general, as well as the specific situation.

To date, while we may know the basic principles involved, and have data for a few conditions, we do not have sufficient data to solve the very practical problem of the illuminating engineer — the prediction of color appearance when one walks into a room and becomes well adapted to any one of the present-day light sources that differs from daylight. To solve this problem of the illuminating engineer, colorimetry enters a new phase, one in which the light source replaces the object as the important variable.

References

1. Ives, H. E.: Color Measurement of Illuminants — A Resume." Trans. I.E.S., 5, 189-207, 1910.
2. Judd, D. B.: *Color in Business Science, and Industry*, 401 pp., Wiley, 1952.
3. O.S.A. Committee on Colorimetry: *The Science of Color*, 385 pp., Crowell, 1953.
4. Nickerson, D.: Artificial Daylighting for Color Grading of Agricultural Products, *Jour. Opt. Soc. Amer.*, 29, 1-9, 1939.
5. Nickerson, D.: The Illuminant in Textile Color Matching, An Illuminant to Satisfy Preferred Conditions of Daylight-Match, Illuminating Engineering, Vol XLIII, 416-464, 1948.
6. Gibson, K. S.: Approximate Spectral Energy Distribution of Skylight, (A), *Jour. Opt. Soc. Amer.*, 30, 88, 1940.
7. Nickerson, D.: *Computational Tables for Use in Studies of Artificial Daylight*, U. S. Department of Agriculture (Pfocessed), 1940.
8. Nickerson, D.: *Progress Report on Color Rendition Studies.* AMS-126, 24 pp., June 1956, U .S. Department of Agriculture (Processed).
9. Judd, D. B.: A New Look at the Measurement of Light and Color. Paper on IES program, Atlanta meeting, Sept. 1957.
10. Kelly, K. L.: Color Designations for Lights, *Jour. Opt. Soc. Amer.*, 33, 627-632, 1943.
11. Newhall, S. M., Nickerson, D., and Judd, D. B.: Final Report of the O.S.A. Subcommittee on the Spacing of the Munsell Colors, *Jour. Opt. Soc. Amer.*, 33, 385-418, 1943.
12. Nickerson, D.: Interrelation of Color Specifications, *TAPPI Technical Assn. Papers* (pp. 472-490), 1947; and TAPPI Section of *Paper Trade Jour.*, 125, No. 2, et seq., July-December 1947.
13. Burnham, R. W.: Comparison of Color Systems with Respect to Uniform Visual Spacing, *Jour. Opt. Soc. Amer.*, 39, 387-392, 1949.
14. Nickerson, D., Judd, D. B., and Wyszecki, G.: Uber eine Transformation des Normalenzsystems in ein empfindungsgemäss gleichabständiges System auf der Grundlage des Munsell-Systems, *Die Farbe*, 4, 285-288, 1955.
15. Barr, A. C., Clark, C. N., and Hessler, J.: Evaluation of Color Rendition by Fluorescent Lamps — An Exploratory Study Illuminating Engineering, Vol. XLVII, 649-656, 1952.
16. Nickerson, D.: The Specification of Color Tolerances, *Textile Research*, 6, 505-514, 1936.
17. Helson, H., Judd, D. B., and Warren, M. H.: Object-Color Changes from Daylight to Incandescent Filament Illumination, Illuminating Engineering, Vol. XLVII, 221-233, 1952.
18. Helson, H., Judd, D. B., and Wilson, M.: Color Rendition with Fluorescent Sources of Illumination, Illuminating Engineering, 51, 329-346, 1956.
19. Burnham, R. W., Evans, R. M., and Newhall, S. M.: Influence on Color Perception of Adaptation to Illumination, *Jour. Opt. Soc. Amer.*, 42, 597-605, 1952.
20. Burnham, R. W., Evans, R. M., and Newhall, S. M.: Prediction of Color Appearance with Different Adaptation of Illuminations, *Jour. Opt. Soc. Amer.*, 47, 35-42, 1957.
21. Nickerson, D., and Wilson, D. H.: Munsell Reference Colors Now Specified for Nine Illuminants, Illuminating Engineering, Vol. XLV, 507-517, 1950.
22. MacAdam, D. L.: Perceptions of Colors in Projected and Televised Pictures, *Jour. Soc. Tel. and Mo. Pic.* 65, 455. (1956).

DISCUSSION

C. N. CLARK:* Congratulations to Miss Nickerson for an excellent, highly readable and comprehensive paper. As indicated in the first part, choice of a standard source presents many problems. In general, standard sources appear to be chosen primarily so as to provide familiar color rendition, by being spectrally similar to commonly used natural or artificial sources, but with compromises as necessary for practical use in test work. Thus, it is logical to accept as formal standards Planckian radiators to 6000 K, and Abbot-Gibson daylight at higher color temperatures.

There are two drawbacks to these standards, as well as the series B standards mentioned in the paper:

(1) They cannot be made to match test source chromaticities that differ very much from the Planckian locus (such as mercury lamps or soft white fluorescent lamps).

(2) Their energy curves are "bumpy" in the higher color temperature range. Thus a test source with a smooth energy curve (logically a better color rendering source than the "bumpy" standard) would, by most rating systems, be unfairly penalized because it differed from the standard source. This difficulty stems from the fact that the standard source may not be the "best possible" or "ideal" source for color rendering. Of course, there are various opinions of what the ideal source might be, and of the criteria for selecting or defining such a source.

It is difficult to evaluate how serious these two drawbacks may be. Quite possibly they are not significant for today's practical sources. However, there may be a way to find the ideal source for use as a formal standard. Actually, it would be a *series* of ideal sources, one for each possible test source chromaticity in the white area, *on or off* the Planckian locus. It might be determined thus:

First, assume that there is such an ideal source at each chromaticity point (and thus for each possible state of color adaptation, assuming that the observer always adapts to the source color).

Second, assume that each ideal source should provide maximum perceived color separation (maximum color contrast) of a wide gamut of colors lighted by it.

Third, at each of a variety of source chromaticities, find the spectral energy distribution that yields maximum perceived color separation of a set of appropriately selected test object colors. This might be done by using a high speed data processing machine. The procedure would be to systematically vary the energy distribution of sources of constant chromaticity; calculate and average the color shifts of the test colors on a perceptually uniform (or nearly so) scale; and then pick, as the ideal source at that chromaticity, the energy distribution that gives maximum average contrast among the test colors.

Fourth, having done this for a variety of source chromaticities, derive a formula for ideal source spectral energy distribution at any chromaticity, as a function of chromaticity.

I have no idea what such "ideal" source curves may look like. At first thought, they may be similar to Planckian radiators. At any rate, such "ideal source" data, if possible to derive, could give us a better insight into the overall optimum source for seeing colors and color differences in general (that is, the source, regardless of chromaticity, that provides maximum object color separation, for an observer adapted to it), and a better baseline from which to measure the color rendition of practical sources.

The lack of a definite, proven "ideal source" is probably not too serious at this stage of the development of color rendition specification. Certainly, as Miss Nickerson has well stated, the need for continued work toward finding ways of expressing color appearance and color shift as they are perceived in the consciousness of a human observer, rather than in purely objective psychophysical terms, is of greatest importance.

D. B. JUDD:* The author is to be congratulated for a clear presentation of the factors that have to be considered in the development of a method for specifying the color-rendition properties of a light source. Considering its brevity the treatment is remarkably exhaustive, and the treatment is made concrete with little additional space by including the results of computations plotted on the Adams chromatic-value diagram (Figs. 7 and 8). Note that Fig. 7 shows the computed chromaticities of all 18 Munsell samples for each of the 9 sources studied. The author points out that the chromaticity differences computed for any given sample caused by changing from one source to another of the same chromaticity (such as from standard warm-white to de-luxe warm-white), are correctly shown on this plot, and properly warns us that any interpretation of differences from one group of sources to another would be unwarranted because "we have no way of knowing how the groups should be displaced to account for adaptation to the several light sources." It may be worth while to point out that the "v. Kries type of transformation" built into the Adams chromatic-value diagram is almost certainly wrong because the primaries of the transformation (those of the CIE system) are far outside the range of permissible primaries found by recent studies of chromatic adaptation by Helson,[18] Burnham,[19, 20] and MacAdam.[22] These three studies do not agree well, and MacAdam's work, in particular, suggests that no single v. Kries type of transformation, regardless of choice of primaries, can accord precisely with the facts; but the coordinate systems supported by any of these recent studies afford a closer approximation than that yielded by the Adams chromatic-value diagram. The use of this diagram in Fig. 8 with the network of constant Munsell hue lines and constant Munsell chroma lines is still very helpful as long as it is realized that the crosses representing computations for Source A are already adjusted to take approximate account of adaptation. Thus if the tri-stimulus values, X_a, Y_a, Z_a, are found by computation for a sample illuminated by Source A, the very first step in computing chromatic values, V_x, V_y, V_x, is to find the ratios:

$$X_a/(X_a)_{\mathrm{MgO}},\ Y_a/(Y_a)_{\mathrm{MgO}},\ Z_a/(Z_a)_{\mathrm{MgO}}$$

and it is obvious that these ratios will all be unity if the sample is the magnesium-oxide reflectance standard. This accords with the experimental fact that a white surface like MgO, illuminated by a nondaylight source still is judged because of adaptation to appear approximately white. The use of these ratios is a "v. Kries type of transformation" spoken of by the author; but, since the primaries referred to (the CIE primaries) are known to be inapplicable, in general, for an account of the facts of chromatic adaptation, the points (shown as crosses in Fig. 8) give an increasingly poorer approximation to the facts as the chroma of the sample departs more and more from zero. Compare the points (shown as dots on Fig. 8), located by the Burnham prediction formula with the crosses for each sample in turn. Note that the distance between each two such points increases regularly with chroma. The dots give a more reliable indication of the influence of adaptation to source

*General Electric Co., Nela Park, Cleveland, Ohio.

*National Bureau of Standards, Washington, D. C.

TABLE A — Color distortions introduced by the Deluxe daylight fluorescent lamp relative to those introduced by the Standard daylight fluorescent lamp.

Munsell Notation of Color Sample	$100\,\Delta E_N$ (Deluxe) / ΔE_N (Standard)	$100\,D$ (Deluxe) / D (Standard)
5 Y 6/4	43	43
10 Y 6/6	67	75
2.5 GY 6/6	192	75
5 GY 6/8	117	89
7.5 GY 6/6	40	67
10 GY 6/6	21	69
2.5 G 6/6	19	29
10 G 6/4	24	36
10 BG 6/4	9	33
10 B 6/4	37	29
5 PB 6/8	72	75
10 PB 6/8	133	85
2.5 P 6/8	48	80
5 P 6/8	53	67
10 P 6/8	54	53
5 RP 6/6	66	71
7.5 R 6/4	18	43
7.5 YR 6/4	29	60
Average	52	60

A than the crosses because they are founded upon actual experiment; the crosses are founded only upon the Adams theory of vision[23] whose latest form[24] carries implications regarding chromatic adaptation not supported by any of the presently available, rather widely divergent, sets of experimental data. Compare in Fig. 9 the *A*-vectors (CIE primaries) with the *H*- and *B*-vectors.

I have another comment relating to the simpler, and commercially more urgent, problem of specifying the color rendition of sources relative to a standard of the same chromaticity. This problem is simpler because no general chromatic adaptation is involved, and my comment relative to the number of test samples to be used in the specification and also to the desired color-rendition rating "whether one- or multi-numbered." Although she does not say so explicitly, the author has developed a logical basis for such a rating. This basis is the color distortion introduced by substituting the source to be rated for the standard against which it is rated; see the last four columns of Table II. The first pair of columns (headed ΔE_N) is a thoroughly defensible evaluation of color distortion; the latter pair of columns (headed (x,y)-distance) is a less defensible evaluation chiefly because distance on the (x,y)-diagram in a given region varies importantly in perceptual significance depending on direction. A second defect, minor for this group of test samples, is that (x,y)-distance is a measure simply of the chromatic aspect of the color distortion and neglects the lightness aspect of the distortion. The first row of entries in these four columns indicates that the color distortion, ΔE_N, introduced by the deluxe daylight fluorescent lamp is only $100 \times 0.9/2.1 = 43$ per cent of that introduced by the Standard daylight fluorescent lamp; and the chromatic distortion indicated by (x,y)-distance is likewise $100 \times 15/35 = 43$ per cent. The relative distortion (deluxe to standard) computed this way for all 18 test samples, is given in Table A.

If the 18 test samples used are accepted as a suitable choice for rating fluorescent lamps, either method of rating indicates that this particular deluxe daylight fluorescent lamp causes about half as much color distortion as this particular standard daylight fluorescent lamp. The approximate evaluation of color distortion by means of (x,y)-distance wrongly indicates that the deluxe rendition of each test sample is less distorted than that by the standard fluorescent lamp, but the precise evaluation of color distortion by means of the Nickerson formula indicates that for three of the test samples the deluxe rendition is poorer. The question raised is whether a rating based on the average distortion for a selection of test samples is sufficient for the lamp industry, or should the rating be multi-numbered so as to include the distortions introduced by the lamp for each of a number of individual test samples. Is it valuable to know that this particular deluxe lamp distorts colors in the green-yellow and the purple-blue range more than the standard fluorescent lamp? The subcommittee will have to come up with a good answer to this question.

References

23. Adams, E. Q.: "A Theory of Color Vision," *Psychol. Rev.*, 30, 56 (1923).

24. Adams, E. Q.: "X-Z planes in the 1931 ICI System of Colorimetry," *J. Opt. Soc. Amer.*, 32, 168 (1942).

GUNTER WYSZECKI:* Miss Nickerson's paper provides an excellent insight into the problems which are involved in the measurement and specification of color rendition properties of light sources. In particular, the paper shows very clearly the importance of the choice of reference lamps and discusses various methods of interpreting and subsequently measuring color rendition properties of light sources. The major problem, however, which makes a completely general solution difficult, turns out to be the effect of the chromatic adaptation of the eye. By changing from one light source to another of a different chromaticity, the state of chromatic adaptation of the eye is changing in a way which, so far, cannot be described adequately in quantitative terms.

The work of the IES Subcommittee on Color Rendition is mentioned and their present results are essentially included in the paper. It may, however, be of general interest to mention two other aspects of the color rendition problem not being discussed in the paper, although they are being considered by the subcommittee. One aspect is the psychological phenomenon, the color preference problem. It is known that, for example, the quality of food is often judged by its color and that good quality food does not necessarily have to show its natural color, but preferably a slightly different shade in order to appeal to the consumer. It is admitted that a quantitative consideration of color shifts with respect to color preference makes the specification of color rendition extremely difficult, but it is believed that in some practical cases this psychological factor may have an important bearing on the usefulness of a potential solution of the problem.

The second aspect is the choice of a reference sample which should be made when developing a specification method. The subcommittee so far is studying 18 Munsell paint samples providing an approximately uniform hue circuit at value 5/. Properly measured color shifts observed on those samples by going from one light source to another will essentially be used to derive a method to specify the color rendition properties of a light source with respect to a standard. The question remains whether these 18 Munsell paint samples are an adequate choice for most specification problems, since it is very likely that in general, other materials of different spectral characteristics will be illuminated by the light sources to be specified. It therefore is believed that the inclusion of reference colors which are metameric to the given set of colors with respect to the standard source and the standard observer will provide a more general solution of the problem.

*National Research Council, Ottawa, Ont.

CHARLES W. JEROME:* Since I am a member of the committee whose work is described in this paper I can only corroborate the statements made by Miss Nickerson. I believe she has very lucidly described the crux of the problem and the many complexities which have been encountered in attempting to derive a solution.

I am glad that she can point out the considerable progress that has been made in this direction and can hold out hope that a workable solution will eventually be recommended.

ARTHUR M. WEEKS:** This paper presents the progress which has been made by the various committees with which Miss Nickerson has been associated. I congratulate the author on this paper, but more specifically on the long list of contributions which she has made to the science of color measurement.

The question I ask may seem unfair, but certainly it is of general interest to all concerned with the measurement of color, and particularly, color rendition.

Is it possible at this time, to place any sort of time table which will indicate when we may expect a number system of designation of color rendition?

DOROTHY NICKERSON:† Let me reply first to Mr. Clark's comments, for they concern the first section of the paper, then to comments by Dr. Judd, Dr. Wyszecki, Mr. Jerome and Mr. Weeks.

Mr. Clark points out that while it is logical to accept the suggestion that as a standard we use Planckian radiators to 6000K and curves for Abbot-Gibson for higher color temperatures, he finds two drawbacks to these standards as well as to series B.

I believe there are two lines of thought involved here; one is that for usual work with color, when one expects to obtain good color rendition, a set of reasonably smooth curves seems needed to represent the range of whites from the low color temperature yellowish whites to higher color temperature bluish whites. In my opinion, such curves should follow the pattern of daylight not only in the range of the visible wavelength but out into the ultraviolet and infrared, as far as they may be expected to have any appreciable effect upon perceived colors. For example, the question of extending the curve for *C* illuminant into the ultraviolet already has been raised within CIE committee (W-1.3.1), as it has been also in the work of the Inter-Society Color Council's subcommitte on Problem 18 (colorimetry of fluorescent materials). I do not consider the Abbot-Gibson too "bumpy," certainly these curves must reach a maximum in the blue and then fall off in energy as they approach the ultraviolet if they are to follow the energy distribution of daylight. Eventually we hope to extend these curves into the ultraviolet so that the color of fluorescent samples assessed by means of these data will provide an answer that will agree with the color seen in an average daylight situation for the same samples.

The fact that the Abbot-Gibson series cannot be made to match all test source chromaticities does not seem a valid objection, for no one-dimensional series of smooth spectroradiometric curves can be expected to do this. If any single color or source is to be used as a standard for color rendition, then this would seem to be some sort of "average daylight." Abbot-Gibson at 7400K has been selected as a practical solution for this single standard. If a mercury lamp or a soft white fluorescent lamp is to be tested for color rendition, as Mr. Clark suggests, then the most simple test is to find out how much either lamp changes the "daylight color" of objects. If there should be a reason to test a lamp whose color lies off the Planckian locus to find out how different its color rendition is from a lamp of similar color, but one with a smooth continuous energy distribution, then a special curve could be set up for that particular situation.

The suggestion that there may be some one point in the range of whites, whether on or off the Planckian locus, that could by calculation be found to be an ideal source (by definition one that would provide a maximum separation of perceived colors for a wide gamut of color samples) is interesting, and I would like to see the answer. But if the specifications for such a source were found, and results under it differed from those under average daylight, then we would be faced with considerable confusion, both in practical color matching work now done in daylight and in current studies of uniform color spacing. To be practical such a light source would have to become so cheap and easy to use that it could compete with daylight as the most-used source for observing colors.

Meanwhile, for industries finding it necessary to specify lamps for use in color appraisal the data published here provide a useful standard. The 7400-7500K curve of Abbot-Gibson has been used since its development in 1940 as a standard to which the lighting of cotton classing rooms has been referred, and within the past year the graphic arts industry has made it a part of a new recommended lighting practice for their industry. (See I.E., September 1957.)

This subject of a standard concerns only one phase of the color rendition problem, but it is a very practical one for those who wish to adopt and use an artificial light source for their color appraisal work. Let us now turn to points raised on other phases of the color rendition work.

Dr. Judd's comments serve to amplify several points, and call attention to their importance. For example, few not familiar with the subject can realize what an important bridge was crossed in this color rendition work when a way was found to pull together in a single graph the results for many samples (spread over the hue circuit) each under as many as nine different illuminants. That is a lot of data, yet if a way is not found to pull it together so that the relative shifts can be seen at one time for a whole series of samples (eventually enough to provide good statistical representation for the most-used part of color space) under several different illuminants, then it will not be possible to understand the problem clearly. For committee work it is an absolute necessity that the data be presented in a way that the color relations may be clear to a group of busy men. As Dr. Judd points out, even now it is necessary to warn those who study these diagrams that we do not yet know how the data for results at different levels of illuminant color should be displaced in relation to each other. His discussion should be very helpful to those who want to get down to fundamentals on this.

In regard to Dr. Judd's next point, as my studies into this work have progressed, I am coming more and more to the point of view that already we have a simple way to find a single or a multi-numbered color rendition index, one that can be based on as many or as few samples as one wishes for any given situation.

Conversion of the color results, however they are first obtained, to an appearance specification in terms of Munsell hue, value or chroma will allow a study of the hue, value or chroma rendition properties of any lamp, and then on the basis of a suitable color difference formula, this could be

*Sylvania Electric Products Inc., Salem, Mass.
**Champion Lamp Works, Lynn, Mass.
†Author.

expressed in terms of a single number to cover the overall or average color rendition properties of a light source. Table II illustrates how this is possible.

It should be pointed out that while the "average" or "single-number" result by any other method than one based on uniform color space may sometimes provide an overall figure that agrees with an average for data based on uniform spacing, such a method can be very misleading when it is broken down. Dr. Judd's Table A shows this clearly, for while the "single number" for average results based on the Munsell evaluation is 52, and not too different from 60, which is based on the visually non-uniform space represented by the CIE (x,y) diagram, yet the differences for individual samples vary widely. Dr. Judd raises the question whether a rating based on the average distortion is sufficient for the lamp industry, or should it be multi-numbered so as to include the distortions for any part of color space in which one may be interested. My answer is that if we use the type of method illustrated in Table II we can have both, for in order to obtain a "single number" one already would have the multi-number data.

I should like to point out that Japanese workers Azuma and Mori already have suggested that color rendition results be expressed in terms of Munsell hue, value and chroma differences. My suggestion takes this one step further, and suggests totaling results by use of a color-difference formula as has been done in Tables II and III. It is my considered suggestion that all formulas be developed so that the color of any sample under any or all illuminants can be computed or converted into terms of its "daylight color" (for the present this would be to CIE C), it would then be possible to obtain a Munsell specification for this equivalent "daylight color." Thus already we have at hand an adequate method for a single or a multi-numbered rating of color rendition. To avoid confusion, it might be well to plot these results directly on a Munsell hue-chroma diagram, making note in numbers of the value change. (This too, Dr. Azuma and his co-workers have already done.)

However, it is only *if* or *when*, adequate formulas are developed for predicting the equivalent color in daylight (or C) for colors seen under a given set of standard conditions for such other illuminants as we may be studying, that it will be possible to complete such work. We know how to do it but we still need appropriate information of the Helson and Burnham type of visual studies before we can proceed to wrap up this phase of the work.

The points covered by Dr. Wyszecki are important. He recognizes the lack of information that is mentioned above, and seems to feel less optimistic than the writer about its solution in a not-too-distant future. The preference aspects of color rendition he mentions should be relatively easy to handle if one works on the basis just described, for individual data could be made available for as few or as many samples as needed, and in terms of whatever color factors are important in a given problem. If butter is to be illuminated, then certainly a light source should be used in which the color will not shift toward the green. To be satisfactory, our color rendition specification method must apply to special, as well as to general, cases of color rendition. Perhaps it would help to define these terms (as we have for CIE W-1.3.2) as follows:

Color Rendition: Color rendition (color rendering property) of a light source is a measure of the degree to which the perceived colors of objects illuminated by the source conform to those of the same objects illuminated by a standard source, for specified viewing conditions. The usual conditions are that the observer shall have normal color vision and be adapted to the environment illuminated by each source in turn.

General Color Rendition: Same as color rendition.

Special Color Rendition: Same as color rendition, but restricted to a particular object (or a group of objects of which the particular object is an adequate representative).

To Dr. Wyszecki I would say that no magic is expected of the series of 18 samples being used by the I.E.S. Subcommittee on Color Rendition. They provide for reasonably good hue coverage, and were convenient as a starting point since Barr, Clark and Hessler already had used them in color rendition studies. Their limitation to a single reflectance level, an advantage at present, will have to be remedied for later studies. However, it should be pointed out that groceries, as well as papers, were used by the subcommittee in early tests, and were omitted later after it was found that the shifts recorded for them fell into line with those for the papers when the results were studied in hue order. Papers have the advantage that the same objects can be measured and observed. With groceries or complexions this is not always possible. To be adequate, any final proposal must take into consideration the shifts for colors found in all common situations, and at least some of those not so common.

I want to thank Mr. Jerome for his comments, and Mr. Weeks for his. As for the time table Mr. Weeks inquires about, I believe that the very organization and preparation of the material for this report and its discussion, plus the data requested by the IES subcommittee which is now being assembled for its next meeting, will be enough help in resolving questions about this work so that it should be possible to lay the matter clearly before the committee at its next meeting so that they may then be able to decide whether we should go ahead now on that part of the way we can see clearly, or whether we must wait until we can obtain sufficient information on which to go the whole way in providing a specification for color rendition.

Report of Subcommittee on Color Rendering
I.E.S. Light Sources Committee, October 1963

The I.E.S. subcommittee on Color Rendering of Light Sources herewith reports that at the CIE meetings held in Vienna, June 18-26, 1963, the Experts of CIE E-1.3.2 reached agreement on a CIE Interim Method of Measuring and Specifying Color Rendering of Light Sources. It is based on unanimous recommendations to CIE E-1.3.2 of the 3-man subcommittee (experts of Germany, the Netherlands, and United States) that succeeded in working out a single proposal.

The resulting CIE recommendation is for a "Test-Color Method" based on the colorimetric shift of a group of test objects. It was agreed that the method be considered the fundamental method for the appraisal of color rendering properties of light sources. Supplementary or abridged methods for making routine measurements on individual lamps may be used when they provide results that agree with the recommended Test-Color Method.

The rating consists of a "General Color Rendering Index" based on a set of eight test-color samples recommended in the method. This may be supplemented by a set of "Special Color Rendering Indices" based on these or other special individual samples, six of which are listed in the method— a strong red, yellow, green, blue, and samples representing complexion and foliage colors. The indices are based on a general comparison of the lengths of chromaticity-difference vectors on the 1960 CIE-UCS diagram for samples under a test source against vectors for the same samples under a standard reference illuminant of the same or nearly the same chromaticity.

The eight samples used in computing the General Color Rendering Index include selections of hues that represent the entire hue circuit, each in moderate chromas, and all approximately the same in lightness (Munsell 6 value, 4-8 chroma). Consequently color differences caused by differences in lightness are of little importance in computing the General Color Rendering Index, and the formula for the General Index can be kept very simple.

In the case of the Special Indices, in which samples may vary considerably from the Munsell 6/ level of lightness of the samples used for computing the "General Index," provision is made for assessing the effect of lightness. This is particularly important since changes in both chroma and hue may sometimes be large when there is a lightness difference in samples that have the same chromaticity coordinates.

The General Color Rendering Index, R_a, which may be read from a table provided in the report, is based on the following equation:

$$R_a = 100 - 4.6\ \overline{\Delta E}_a \qquad [1]$$

This is derived from

$$R_a = 100 - 3.7 \times 10^3\ (\overline{\Delta E}_{u,v}) \qquad [1']$$

and $\overline{\Delta E}_a = 800\ \overline{\Delta E}_{u,v}$

in which $\overline{\Delta E}_{u,v}$ represents the average of the vector lengths $\Delta E_{u,v}$ for test samples Nos. 1-8 on the u,v-diagram. Note that formula [1'] is equivalent to formula [3] of the I.E.S. recommended method published in Illuminating Engineering, July 1962. 1/ Thus the CIE General Color Rendering Index is identical with the rating provided by the IES method. The introduction of $\overline{\Delta E}_a$, which is 800 $\overline{\Delta E}_{u,v}$, represents an adjustment that is made in order that the unit $\overline{\Delta E}_a$, when applied to samples computed for Illuminant C, will correspond on the average to the size of one NBS unit of color-difference.

This is an advantage since the unit for the CIE Special Color Rendering Index, R_i, also corresponds to the size of one NBS unit. The Special Index is based on the equation:

$$R_i = 100 - 4.6\ \Delta E_i \qquad [1a]$$

in which ΔE_i represents that vector in three-dimensional UCS space which constitutes a measure of total color-difference, the unit difference being equalized for Illuminant C to the approximate size of an NBS unit of color-difference. These ratings may be computed, or may be read from a table provided in the report. A single table is used for $\overline{\Delta E}_a$, $\overline{\Delta E}_{u,v}$, and ΔE_i. The method for obtaining ΔE_i follows a formula developed by Wyszecki for CIE committee E-1.3.1 that adds to the 1960 CIE-UCS diagram a scale of perceptually uniform spacing of the luminance factor, thus adapting the CIE-UCS diagram to a three-dimensional space.

The ratings resulting from use of equations [1] and [1a] for obtaining the General and Special Indices will be identical when the luminous reflectance of Special samples is the same as that of the average of test samples 1-8 used in the General formula, and when the differences in luminous reflectance are zero. Under such conditions ΔE_i equals ΔE_a.

The method as finally proposed combines the proposals of the IES for a simple vector method on the UCS diagram, with the German, Netherlands, and Japanese proposals for using a color-difference vector in three-dimensional space. The first proposal has been worked into the CIE General Color Rendering Index, and the second has been worked into the CIE Special Color Rendering Indices. Both make use of the CIE-UCS diagram. In the first case, the samples are so chosen that the diagram can be limited to the two-dimensional 1960 form of the CIE-UCS diagram. In the second case, the samples require reference to the three-dimensional space which is supplied by the 1963 CIE-UCS recommendations.

When adequate spectroradiometric data are available the method can be applied to single lamps with very little trouble by use of a desk calculator. For such a case, computations are required for a minimum of eight test colors for each light source. When information is required for many lamps it is convenient, although not necessary, to use electronic computers.

1/ Illuminating Engineering Society. Interim Method of Measuring and Specifying Color Rendering of Light Sources. Illum. Engineering, 57, 471-495 (1962). Available as I.E. reprint, 27 pp. $1.15.

To provide some idea of how these ratings work in practice, rating indices for a number of commonly recognized light sources are listed in table 1. A lamp with an index of 100 is one with color rendering properties that perfectly duplicate those of the standard reference lamp; a lamp with an index of 50 has color rendering properties that on the average shift the colors of objects as much as they are shifted by a standard fluorescent white lamp at 3000K (such as was used in IES subcommittee studies) in comparison to the colors of the same objects under an incandescent reference lamp at 3000K.

The text of the English draft of the CIE E-1.3.2 recommendation, as of September 16, 1963, is attached.

Table 1.--General Color Rendering Index for several lamps by the CIE method[1]

Lamp identification	Reference[2] standard	Rating index	Lamp identification	Reference[2] standard	Rating index
Flu. Std. WW 1	3000K	54	Flu. Std. CW 1	4500K	70
3 mfrs. 2	"	54	3 mfrs. 2	4400K	70
3	"	53	3	"	70
Flu. DeL. WW 1	3000K	66	Sylv. Sup. DeL.	4400K	86
3 mfrs. 2	"	75	Flu. CW - 1950[3]	4500K	84
3	"	77	Macbeth G_2 + filt.	5000K	94
Flu. Soft Wh. 1	3400K	62	Xenon (6250K)	"C"	92
3 mfrs. 2	"	72	"	6000K Pl.	93
3	"	61	"	6500K A-G	94
Flu. Wh. - 1950[3]	3500K	78	Macbeth G_2 + filt.	6500K	92
Flu. Wh. 1	3600K	60	Flu. Daylight 1	6500K	77
3 mfrs. 2	"	62	3 mfrs. 2	6500K	76
3	"	63	3	7000K	78
Flu. Philips 34	3800K	87	Flu. Daylight-1950[3]	6500K	90
Flu. Soft Wh.-1950[3]	3800K	70	Philips Flu.6500K	6500K	92
Macbeth G_2 + filt.	4000K	96	Macbeth-filt.6800K	7000K	94
Macbeth Avlite	4100K	91	Philips Flu. 7000K	7000K	93
Flu. DeL. CW 1	4200K	80	Duro-Test #381	7400K	82
3 mfrs. 2	"	85	DeL. Examolite[4]	7400K	92
3	"	84	Std. Examolite[4]	7400K	80
			Macbeth-filt.7500K	7400K	92

1 The CIE "General" index equals the IES index recommended in 1962.
2 Unless otherwise specified, the reference for lamps 6000K and below is a Planckian distribution; above 6000K, it is an Abbot-Gibson distribution.
3 Manufactured in U.S. prior to 1950 when beryllium was still used.
4 DeLuxe Examolite available since 1956, replaced the old Standard Examolite.

Attachment

Submitted by

Dorothy Nickerson, Chairman
Subcommittee on Color Rendering
IES Light Sources Committee

Oct. 1963
Cotton Div., AMS, USDA
Washington 25, D.C.

Redraft 9/16/63, based on
Draft-Aug. 8, 1963 - dn
Based on Vienna draft
Rtd. Mr. Münch 8/13/63

CIE INTERIM METHOD OF MEASURING AND SPECIFYING COLOUR RENDERING OF LIGHT SOURCES

Recommended by Committee E-1.3.2

1. Purpose

This specification establishes a CIE recommended method of measuring and specifying colour rendering properties of light sources based on the colorimetric shift of a group of test objects, named "Test-Colour Method" for short.

It is agreed by the expert members of E-1.3.2 that this be considered the fundamental method for appraisal of colour rendering properties of light sources and be recommended for type designing as well as for testing individual lamps.

It is agreed also that supplementary or abridged methods for routine measurements on individual lamps may be used when they provide results that agree with the recommended Test-Colour Method.

For definitions of terms used in this specification, see separate CIE-Publication. 1)

2. Scope

This specification applies to most general purpose illuminants of natural and artificial types (e.g., tungsten filament lamps, tubular fluorescent lamps, and all kinds of gaseous discharge electrical lamps except sources of monochromatic or nearly monochromatic radiation such as sodium, etc.).

3. Rating

It is recommended that the rating shall consist of a "General Colour Rendering Index" that may be supplemented by a set of "Special Colour Rendering Indices."

The derivation of colour rendering indices shall be based on a general comparison of the lengths of chromaticity-difference vectors on the 1960 CIE-UCS diagram 2), and will be carried out according to the Test-Colour Method described in sections 4 and 5.

---

1) See "Note of Information on Terminology of Colour Rendering, Committee E-1.3.2," CIE 1963.

2) Interim Method of Measuring and Specifying Color Rendering of Light Sources, Illuminating Engineering, 57 (1962), pp. 471-495.

4. Rating Procedure

4.1 General Remarks

To apply the Test-Colour Method the colorimetric shifts of suitably chosen test colours must be calculated. From these colorimetric shifts colour rendering indices may be found as described in section 5.

In calculating the colorimetric shifts, CIE tristimulus values of the various test colours must be determined for both the light source under test and the reference illuminant. The next step is to transform the tristimulus values into coordinates of the 1960 CIE uniform-chromaticity scale diagram. A correction is then applied for the difference in chromaticity coordinates between the two light sources, and the colorimetric shift is calculated from these corrected coordinates.

As long as the colour difference between test lamp and reference illuminant is kept small (see 4.3), the adjustment may be considered a satisfactory approximation for chromatic adaptation. In the ultimate version of the Test-Colour Method, when wider colour differences between lamps must be considered, it will be necessary that chromatic adaptation receive a more rigorous treatment.

4.2 Reference Illuminant

The appraisal of colour rendering properties of a light source shall be referred always to a "Reference Illuminant," either real or unreal. This reference illuminant shall be of the same or nearly the same chromaticity as the lamp to be tested. (For tolerances, see section 4.3.)

Unless otherwise specified, the reference illuminant for light sources with correlated colour temperature 6000°K or below shall be a Planckian radiator at the nearest colour temperature, and above 6000°K the Abbot-Gibson series of spectral energy distributions of skylight.

In italics — The Abbot-Gibson series shall serve until such time as CIE E-1.3.1 recommends a one-dimensional series of relative energy curves for various phases of daylight, at which time such series shall replace the Abbot-Gibson series above 5000°K.

For special cases, CIE or other specified standard illuminants may serve as the reference illuminant.

In all cases a full description in terms of spectral energy distribution for wavelength intervals no greater than 10 nm over the visible spectrum shall be supplied for reference illuminants.

In italics Since chromaticity standards for general purpose fluorescent lamps of similar names are not the same in all countries, the reference illuminants used in each country for such lamps should accord both with the above requirements and with those of local standards.

4.3 Tolerances for Reference Illuminant

The reference illuminant is intended to be of the same or nearly the same chromaticity as the lamp to be tested. Therefore, it shall be selected to be within 5 mireds of the correlated colour temperature of the test lamp, if this is possible. This tolerance is suggested as a practical limit of difference.

In italics At 3000°K, a difference of 5 mireds (micro-reciprocal degrees) corresponds to about 50°K, while at 7400°K it corresponds to about 250°K. This tolerance specification makes it practical to supply reference tables in Annex 1, Table 3. For any additional reference illuminants similar data must be calculated.

If the chromatic difference between test lamp and reference illuminant is greater than this tolerance in any direction, the resulting colour rendering indices may be expected to become less accurate.

In all cases the reference illuminant shall be indicated in brackets after the rating figure.

Examples for computing differences are included in Annex 1, Table 4. As illustrated, the difference between test lamp and reference illuminant is applied as a tolerance adjustment to the (u,v)-data of each sample under the test source. Test lamps in both illustrations are Standard Warm White fluorescent. The first case refers to the pair of lamps used by the I.E.S. committee 2) to set the size of difference at which a test lamp rates 50; the second case refers to a lamp from commercial stock, rated against Planckian 3000°K.

4.4 Test-Colour Samples

For calculating the "General Colour Rendering Index" recommended by this method a set of eight test-colour samples is listed by CIE sample number, Munsell notation and production number, and by spectral reflectance in Table 1 of Annex 1. For daylight these samples cover the hue circuit, are moderate in saturation, and are approximately the same in lightness (Munsell value 6/).

For special purposes additional test-colour samples may be used. Results for these additional samples are not included in calculating the General Colour Rendering Index. Data for special samples representing a strong red, yellow, green, and blue, and representing complexion and foliage colours, are supplied for Munsell samples,

Nos. 9-14, in Table 2 of Annex 1. In daylight these samples vary widely in lightness and saturation. Other test samples may be used. They must be based always on accurate spectral reflectance characteristics of the individual test samples (i).

4.5 Determination of 1931 CIE Tristimulus Values for Colours of Test Samples

From a suitably accurate spectroradiometric measurement of the test lamp, combined with the spectral reflectance data of the test samples as given in Annex 1, 1931 CIE tristimulus values or chromaticity coordinates of the lamp and test samples shall be determined. They shall be calculated to four decimal places of (x,y).

In italics   If direct measurements are used, they shall equal the precision required above.

4.6 Transformation into the 1960 CIE-Uniform Chromaticity Scale Coordinates

Colorimetric data must now be transformed from the 1931 CIE values (X,Y,Z,x,y) to the (u,v)-coordinates of the 1960 CIE-uniform chromaticity scale diagram. Transformation may be made by using either of the following formulas, carried to four decimal places:

$$u = 4X/\ (X+15Y+3Z),\ \text{or}\ u = 4x/\ (-2x+12y+3)$$
$$v = 6Y/\ (X+15Y+3Z),\ \text{or}\ v = 6y/\ (-2x+12y+3)$$

5. Calculation of Colour Rendering Indices

5.1 Designation of Colour Rendering Index

The colour rendering index is designated by the letter R. The "General Colour Rendering Index" derived in accord with clause 5.2 is signified by the symbol R_a. The "Special Colour Rendering Indices" derived in accord with 5.3 are designated by the symbol R_i (i = 1, 2, ... corresponding to the number of any individual test sample that may be studied).

5.2 Calculation of General Colour Rendering Index

The General Colour Rendering Index R_a may be read from Table 5 of Annex 1, or derived by use of the following equation on which Table 5 is based:

$$R_a = 100 - 4.6\ \overline{\Delta E}_a \qquad [\ 1\ ]$$

derived from

$$R_a = 100 - 3.7 \times 10^3\ (\overline{\Delta E}_{u,v})$$

and

$$\overline{\Delta E}_a = 800\ \overline{\Delta E}_{u,v}$$

in which $\overline{\Delta E}_{u,v}$ represents the average of the vector lengths $\Delta E_{u,v}$ for the test samples Nos. 1-8 on the (u,v)-diagram, and $\overline{\Delta E}_a$ represents these values after adjustment to provide a unit of colour-difference that (under C Illuminant) corresponds on the average to one NBS unit: 3)

$$\overline{\Delta E}_a = \frac{\Sigma \Delta E_a}{8}$$

The several ΔE_a for the individual test samples used in the General Index are derived from the following equation:

$$\Delta E_a = 800[(u_{o,i} - u'_{K,i})^2 + (v_{o,i} - v'_{K,i})^2]^{\frac{1}{2}} \qquad [2]$$

where:

$u_{o,i}$, $v_{o,i}$ are the UCS-coordinates of any test samples (i) under the reference illuminant (o).

$u'_{K,i}$, $v'_{K,i}$ are the UCS-coordinates of any test samples (i) after adjustment for $(u_o - u_K)$ and $(v_o - v_K)$.

These adjusted coordinates are given by

$$u'_{K,i} = u_{K,i} + (u_o - u_K); \; v'_{K,i} = v_{K,i} + (v_o - v_K)$$

where:

$u_{K,i}$, $v_{K,i}$ are the UCS-coordinates of any test samples (i) under the test lamp (K).

u_o , v_o are the UCS-coordinates of the reference illuminant (o).

u_K , v_K are the UCS-coordinates of the test lamp (K).

In italics The factor 4.6 in formula [1] includes the factor (3.7×10^3) ~~used in formula [1a]~~ and the factor 800 applied to $\Delta E_{u,v}$. The factor (3.7×10^3) serves to convert the average vector lengths ($\Delta E_{u,v}$) under the IES committee 2) 3000°K standard fluorescent lamp to a rating of 50 when the reference illuminant is the incandescent lamp used in the IES committee work. The factor of 800 applied to $\Delta E_{u,v}$ serves to provide a unit of colour-difference ΔE_a that is approximately the size of the NBS unit of colour

---

3) See G. Wyszecki, Proposal for a New Color-Difference Formula, J.Opt. Soc.Amer., 53 (Oct . 1963). This proposal is the basis for a recommendation by CIE E-1.3.1 in 1963 that adds to the 1960 CIE-UCS diagram a scale that involves perceptually uniform spacing of the luminance factor of object colours, thus converting it to a three-dimensional space. In such a space computations of colour differences may be carried out without restriction to colours of equal luminance.

difference, ΔE. The 800 (an approximation for $61 \times 13 = 793$) takes into account 61, the average lightness index of the eight samples used in the General Index, and the 13 which adjusts for the difference in size of units of lightness index and (u,v)-units of chromaticity. (See 5.3 for explanation).

For the samples used in the General Index, differences in luminous reflectance are so small that they can be considered insignificant, and in the interest of simplicity are omitted. See Table 6 for average difference, $\overline{\Delta E}_a$ and $\overline{\Delta E}_i$, for samples 1-8.

5.3 Calculation of Special Colour Rendering Indices

The chromaticity differences for individual or special test colour samples may provide useful information in addition to a General Index. Therefore, for samples in the general set listed in Table 1, Annex 1, or for other test samples, particularly those listed in Table 2, Annex 1, a Special Colour Rendering Index may be derived. This index includes evaluation of any lightness differences that may occur.

When test samples other than those recommended in Tables 1 and 2 of Annex 1 are used, accurate spectral reflectance data are required for them.

The Special Colour Rendering Index R_i, based on ΔE_i, may be read from Table 5 of Annex 1, or derived from the formula:

$$R_i = 100 - 4.6\,\Delta E_i \qquad [1a]$$

To obtain ΔE_i the following formula (which accords with the UCS colour-difference formula recommended provisionally in 1963 by E-1.3.1) is applied. It is the general case of formula [2].

$$\Delta E_i = \Big\{[W_{K,i} - W_{o,i}]^2 + 13^2[W_{K,i}(u_{K,i} - u_K) - W_{o,i}(u_{o,i} - u_o)]^2 + 13^2[W_{K,i}(v_{K,i} - v_K) - W_{o,i}(v_{o,i} - v_o)]^2\Big\}^{\frac{1}{2}} \qquad [3]$$

in which:

$$W_{K,i} = 25Y_{K,i}^{\frac{1}{3}} - 17; \quad W_{o,i} = 25Y_{o,i}^{\frac{1}{3}} - 17 \qquad [4]$$

W being the lightness index, and the subscripts the same as in 5.2. The factor 13 is introduced to equalize, for standard conditions, the size of the (W) and (u,v) units.

Formula [1a] agrees with the general formula [1] when the luminous reflectance is 61, the same as that of test samples 1-8, and the differences in luminous reflectance are zero. Under these conditions ΔE_i equals ΔE_a. For samples 1-8, the difference between use of formulas [2] and [3], ΔE_a and ΔE_i, is illustrated for a Standard Warm White fluorescent lamp in Table 6 of Annex 1.

In italics Samples on which the General Index is based have only moderate variation in reflectance from one part of the spectrum to another. Thus extreme variations in luminous reflectance are avoided under any general purpose light source. On this account, appraisal of the color rendering of such sources by this group of samples (Nos. 1-8) can be limited to chromaticity shift, as in formula [2], without the need for evaluation of luminous reflectance which is included in formula [3].

Annex 1

Table 1.--Spectral reflectance of CIE E-1.3.2 test set of samples, Nos. 1-8, to be used in calculating General Colour Rendering Index recommended by E-1.3.2.

Table 2.--Spectral reflectance of CIE E-1.3.2 samples, Nos. 9-14, for use in calculating Special Colour Rendering Indices in accord with E-1.3.2 recommendations.

Table 3.--1960 CIE-UCS data for CIE test samples under a selection of reference illuminants, extending from incandescent, at 2850°K, to blue sky, at ∞.

Table 4.--Examples for computing colorimetric shift for CIE test samples after correction for difference in colour coordinates between test and reference illuminants.

Table 5.--Colour rendering indices, based on equivalent average vector lengths $\Delta E_{u,v}$ or on ΔE_a or ΔE_i as computed from formulas [2] and [3].

Table 6.--Example of differences between ΔE_a, based on formula [2] and ΔE_i, based on formula [3]: For 14 CIE test samples under Standard Warm White fluorescent lamp.

Table 1.--Spectral reflectance of CIE E-1.3.2 test set of samples, Nos. 1-8, to be used in calculating General Colour Rendering Index recommended by E-1.3.2

Wave-Length	CIE Sample Number							
	1	2	3	4	5	6	7	8
	Munsell Book Notation and Production Number							
nm	7.5R 6/4 4277	5Y 6/4 6329	5GY 6/8 4365	2.5G 6/6 6212	10BG 6/4 4881	5PB 6/8 4892	2.5P 6/8 3837	10P 6/8 6432
400	26.3	11.4	7.5	11.9	32.1	42.0	56.5	34.5
10	25.8	12.1	7.6	12.7	32.7	50.5	57.3	47.4
20	25.0	12.4	7.6	13.1	33.4	53.0	57.5	50.2
30	24.3	12.5	7.5	13.8	34.3	54.5	57.0	49.4
40	23.6	12.6	7.5	14.8	35.5	55.8	55.8	47.4
450	23.1	13.0	7.6	16.5	36.9	57.0	53.5	45.0
60	22.6	13.4	7.9	19.1	39.1	56.8	50.1	42.4
70	22.1	14.1	8.7	23.5	41.3	55.5	46.0	39.2
80	22.0	15.4	11.2	28.8	42.6	53.2	41.8	36.1
90	22.2	17.8	15.2	34.0	43.0	50.0	37.2	33.3
500	22.9	21.2	20.3	37.9	42.4	46.2	33.2	30.7
10	23.2	24.8	24.7	40.0	41.3	42.5	30.9	29.0
20	23.1	26.7	28.5	40.5	39.9	38.7	29.0	27.7
30	23.3	27.4	34.8	39.5	38.2	35.0	27.2	26.3
40	24.2	27.9	40.2	37.6	36.2	31.7	26.4	25.6
550	25.9	28.9	41.0	35.0	33.9	28.6	26.6	26.0
60	27.9	30.7	39.0	32.0	31.6	25.9	26.7	27.1
70	30.6	33.0	35.8	28.7	29.1	24.0	26.3	27.9
80	35.0	34.4	32.3	25.3	26.7	23.1	26.1	28.5
90	40.0	35.0	29.2	21.9	23.8	22.7	27.7	30.3
600	43.5	35.1	27.1	19.0	21.5	22.6	31.0	35.7
10	45.3	35.1	25.8	17.3	19.9	22.6	35.3	44.5
20	46.1	35.0	24.7	16.4	19.0	22.9	38.7	54.2
30	46.3	34.8	23.5	15.8	18.5	23.9	41.0	62.0
40	46.3	34.7	22.6	15.5	18.1	25.0	43.1	66.5
650	46.2	34.5	22.2	15.2	17.9	26.5	44.9	69.3
60	46.3	34.3	22.5	15.2	17.9	27.5	46.4	71.1
70	46.5	34.1	23.6	15.5	18.5	28.5	47.4	72.3
80	46.7	33.9	25.7	16.2	19.1	29.0	48.0	73.0
90	47.0	33.7	29.5	16.9	19.7	29.8	48.5	73.5
700	47.4	33.6	34.9	17.4	20.4	31.0	49.5	73.9
405[1]	26.0	11.8	7.5	12.3	32.4	46.3	57.0	41.0
436	23.9	12.6	7.5	14.4	35.0	55.3	56.3	48.2
546	25.2	28.5	40.8	36.1	34.8	29.8	26.5	25.8
578	34.1	34.2	33.0	26.0	27.2	22.9	26.1	28.3

[1]Use for calculating additional energy at mercury lines of fluorescent lamps.

Table 2.--Spectral reflectance of CIE E-1.3.2 samples, Nos. 9-14, for use in calculating Special Colour Rendering Indices in accord with E-1.3.2 recommendations

Wave-Length	CIE Sample Number					
	9	10	11	12	13	14
	Munsell Book Notation And Production Number					
	4.5 4/13	5Y 8/10	4.5G 5/8	3PB 3/11	5YR 8/4	5GY 4/4
nm	4785	4991	3943	2312	6324	6157
400	5.3	6.8	13.0	7.8	28.0	4.0
10	5.2	7.0	11.9	6.6	35.0	4.1
20	5.1	7.1	11.1	7.7	36.8	4.3
30	4.9	7.4	10.7	12.6	37.3	4.4
40	4.7	7.8	10.8	21.4	37.6	4.5
450	4.3	8.5	11.3	30.8	38.1	4.6
60	3.9	9.7	12.6	35.5	38.6	4.8
70	3.4	11.6	15.2	35.0	39.4	5.1
80	3.1	14.6	19.7	31.5	40.7	5.6
90	2.9	19.4	25.8	26.4	42.7	6.4
500	2.9	26.9	33.3	20.9	45.4	7.7
10	3.1	37.4	36.5	15.8	47.3	9.4
20	3.2	47.7	35.5	11.2	48.1	11.1
30	3.3	56.0	32.2	7.7	48.6	13.6
40	3.4	62.6	27.8	5.2	49.5	15.4
550	3.6	67.0	23.3	3.6	51.9	15.9
60	4.2	69.6	19.3	2.6	56.7	15.1
70	4.9	71.1	15.7	2.0	63.4	13.6
80	6.1	71.9	12.8	1.7	69.7	12.1
90	10.5	72.3	10.9	1.6	73.5	10.9
600	19.5	72.4	9.8	1.6	75.5	10.0
10	34.5	72.5	9.2	1.6	76.4	9.5
20	51.8	72.6	8.7	1.6	76.7	9.1
30	65.7	72.8	8.2	1.8	76.7	8.8
40	73.5	73.0	8.0	1.9	76.7	8.6
650	77.7	73.4	8.0	2.0	76.7	8.6
60	80.1	73.8	8.3	2.4	76.6	8.7
70	81.7	74.4	9.0	2.7	76.6	9.4
80	83.0	75.0	10.5	3.6	76.6	10.5
90	84.0	75.8	12.8	5.7	76.6	12.6
700	84.9	76.5	16.5	9.9	76.5	15.6
405/8[1]	5.3	6.9	12.5	7.2	32.5	4.1
436	4.8	7.5	10.8	17.0	37.5	4.5
546	3.5	65.5	25.5	4.0	51.0	15.9
577/9	5.9	71.5	13.1	1.8	68.3	12.4

[1] Use for calculating additional energy at mercury lines of fluorescent lamps.

Table 3.--1960 CIE-UCS data for CIE test samples under a selection of reference illuminants, extending from incandescent, at 2850°K to blue sky, at ∞

To be supplied

Note: This table is to be the same as Appendix II of the IES report (pp. 26-27). Or, it can be made up new on several pages from the tables in DN's mimeographed "Reference Data" report. In all cases the Y data should have the decimal point moved, so that Y = 100.00 (not 1.0000).

Data for more reference standards than in the IES report are available. They are indexed below to the pages of the "Reference Data" report which includes the data. A new table, including them in order and correcting for the decimal point in the Y values can be made, making sure that data for the #5 sample is for 10BG 6/4 (not 10B).

Reference lamp identification		DN-IBM number	Data on page no. 1/	Reference lamp identification		DN-IBM number	Data on page no. 1/
CIE A	2850°K	7	11	Planckian,	4800°K	22	12
B	4800°K	8	11	cont'd.	5000°K	23	12
C	6740°K	28	11		5500°K	24	13
Planckian*	2900°K	9	11		6000°K	25	13
	3000°K	10	11				
	3100°K	11	11	Abbot-Gibson	6100°K	1	13
	3200°K	12	11		6500°K	2	13
	3300°K	13	11		7000°K	3	13
	3400°K	14	11		7400°K	38	13
	3500°K	15	12		8000°K	4	13
	3600°K	16	12		9300°K	5	13
	3800°K	51	16		11,000°K	55	17
	3900°K	52	16		14,000°K	56	17
	4000°K	17	12		∞	6	13
	4100°K	53	12				
	4200°K	18	12	From IES Study			
	4400°K	19	12				
	4500°K	20	12	Incandescent	3000°K	29	14 2/
	4600°K	21	12	Std. WW flu.	3000°K	30	14 3/

1/ "Reference Data" report, July 1962-June 1963, D.N., copies supplied each of you.
2/ Data for #5 sample, 10BG 6/4 (Y = 29.05, u = 0.2056, v = 0.3443).
3/ (Y = 28.45, u = 0.2184, v = 0.3413), for #5 sample.

* The black body data used are based on Moon's tables 1938, and 1947, in which C_2 = 14320.

Table 4.--Examples for computing colorimetric shift for CIE test samples after correction for difference in colour coordinates between test and reference illuminants

For: Reference illuminant (o): 3000K, Incandescent:* $u_o = 0.2515$ $v_o = 0.3481$
Test source (K): 3000K, Std. Flu. W.W.:* $u_K = 0.2479$ $v_K = 0.3463$ $\Delta u_{o-K} = +0.0036$ $\Delta v_{o-K} = +0.0018$

Test sample (i) identification: CIE No.	Munsell notation	Under reference illuminant (o): $u_{o,i}$	$v_{o,i}$	Under test source (K): $u_{K,i}$	$v_{K,i}$	Under test source adj. (K'): $u'_{K,i}$	$v'_{K,i}$	Difference under reference illuminant and test source: $u_{o,i}-u'_{K,i}$	$v_{o,i}-v'_{K,i}$	$(u_{o,i}-u'_{K,i})^2$	$(v_{o,i}-v'_{K,i})^2$	SUM: $(u_{o,i}-u'_{K,i})^2 + (v_{o,i}-v'_{K,i})^2$	$\sqrt{SUM}$: $\Delta E_{u,v}$	ΔE_a: $800\ \Delta E_{u,v}$
1	7.5R 6/4	0.2995	0.3514	0.2804	0.3513	0.2840	0.3531	0.0155	0.0017	0.00024025	0.00000289	0.00024314	0.0156	12.5
2	5Y 6/4	.2731	.3597	.2614	.3611	.2650	.3629	.0081	.0032	.00006561	.00001024	.00007585	.0087	7.0
3	5GY 6/8	.2340	.3672	.2308	.3687	.2344	.3705	.0004	.0033	.00000016	.00001089	.00001105	.0033	2.6
4	2.5G 6/6	.1977	.3587	.2116	.3595	.2152	.3613	.0175	.0026	.00030625	.00000676	.00031301	.0177	14.2
5	10BG 6/4	.2056	.3443	.2184	.3413	.2220	.3431	.0164	.0012	.00026896	.00000144	.00027040	.0164	13.1
6	5PB 6/8	.2206	.3295	.2289	.3212	.2325	.3230	.0119	.0065	.00014161	.00004225	.00018386	.0136	10.9
7	2.5P 6/8	.2720	.3325	.2600	.3245	.2636	.3263	.0084	.0062	.00007056	.00003844	.00010900	.0104	8.3
8	10P 6/8	.3050	.3383	.2792	.3326	.2828	.3344	.0222	.0039	.00049284	.00001521	.00050805	.0225	18.0
												Average.....	0.0135	10.8

$R_a = 50$ (Based on $\overline{\Delta E}_{u,v} = 0.0135$; or $\overline{\Delta E}_a = 10.8$)

For: Reference illuminant (o): 3000K, Planckian: $u_o = 0.2500$ $v_o = 0.3474$
Test source (K): 3000K, Std. flu. W.W.:# $u_K = 0.2481$ $v_K = 0.3478$ $\Delta u_{o-K} = +0.0019$ $\Delta v_{o-K} = -0.0004$

CIE No.	Munsell notation	$u_{o,i}$	$v_{o,i}$	$u_{K,i}$	$v_{K,i}$	$u'_{K,i}$	$v'_{K,i}$	$u_{o,i}-u'_{K,i}$	$v_{o,i}-v'_{K,i}$	$(u_{o,i}-u'_{K,i})^2$	$(v_{o,i}-v'_{K,i})^2$	SUM	$\Delta E_{u,v}$	ΔE_a
1	7.5R 6/4	0.2976	0.3510	0.2812	0.3523	0.2831	0.3519	0.0145	0.0009	0.00021025	0.00000081	0.00021106	0.0145	11.6
2	5Y 6/4	.2741	.3594	.2618	.3617	.2637	.3613	.0077	.0019	.00005929	.00000361	.00006290	.0079	6.3
3	5GY 6/8	.2325	.3671	.2308	.3690	.2327	.3686	.0002	.0015	.00000004	.00000225	.00000229	.0015	1.2
4	2.5G 6/6	.1963	.3582	.2110	.3605	.2129	.3601	.0166	.0019	.00027556	.00000361	.00027917	.0167	13.4
5	10BG 6/4	.2040	.3435	.2179	.3433	.2198	.3429	.0158	.0006	.00024964	.00000036	.00025000	.0158	12.6
6	5PB 6/8	.2189	.3283	.2287	.3241	.2306	.3237	.0117	.0065	.00013689	.00004225	.00017914	.0134	10.7
7	2.5P 6/8	.2700	.3313	.2606	.3271	.2625	.3267	.0075	.0046	.00005625	.00002116	.00007741	.0087	7.0
8	10P 6/8	.3028	.3375	.2802	.3348	.2821	.3344	.0207	.0031	.00042849	.00000961	.00043810	.0209	16.7
												Average.....	0.0124	9.9

$R_a = 54$ (Based on $\overline{\Delta E}_{u,v} = 0.0124$; or $\overline{\Delta E}_a = 9.9$)

* Used in IES study. 2)

\# Commercial lamp.

Annex 1, Table 5

Table 5.--Colour rendering indices, based on equivalent average vector lengths $\overline{\Delta E}_{u,v}$ or on $\overline{\Delta E}_a$ or $\overline{\Delta E}_i$ as computed from formulas [2] and [3].

R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$
100	0.0000	0.0	75	0.0068	5.4	50	0.0135	10.8	25	0.0203	16.2
99	.0003	0.2	74	.0070	5.6	49	.0138	11.0	24	.0205	16.4
98	.0005	0.4	73	.0073	5.8	48	.0140	11.2	23	.0208	16.6
97	.0008	0.6	72	.0076	6.1	47	.0143	11.4	22	.0211	16.9
96	.0011	0.9	71	.0078	6.3	46	.0146	11.7	21	.0213	17.1
95	.0014	1.1	70	.0081	6.5	45	.0149	11.9	20	.0216	17.3
94	.0016	1.3	69	.0084	6.7	44	.0151	12.1	19	.0219	17.5
93	.0019	1.5	68	.0086	6.9	43	.0154	12.3	18	.0221	17.7
92	.0022	1.8	67	.0089	7.1	42	.0157	12.6	17	.0224	17.9
91	.0024	1.9	66	.0092	7.4	41	.0159	12.8	16	.0227	18.2
90	.0027	2.2	65	.0095	7.6	40	.0162	13.0	15	.0230	18.4
89	.0030	2.4	64	.0097	7.8	39	.0165	13.2	14	.0232	18.6
88	.0032	2.6	63	.0100	8.0	38	.0167	13.4	13	.0235	18.8
87	.0035	2.8	62	.0103	8.2	37	.0170	13.6	12	.0238	19.0
86	.0038	3.0	61	.0105	8.4	36	.0173	13.8	11	.0240	19.2
85	.0041	3.3	60	.0108	8.6	35	.0176	14.1	10	.0243	19.4
84	.0043	3.4	59	.0111	8.9	34	.0178	14.3	9	.0246	19.7
83	.0046	3.7	58	.0113	9.0	33	.0181	14.5	8	.0248	19.9
82	.0049	3.9	57	.0116	9.3	32	.0184	14.7	7	.0251	20.1
81	.0051	4.1	56	.0119	9.5	31	.0186	14.9	6	.0254	20.3
80	.0054	4.3	55	.0122	9.7	30	.0189	15.1	5	.0257	20.5
79	.0057	4.6	54	.0124	9.9	29	.0192	15.3	4	.0259	20.7
78	.0059	4.7	53	.0127	10.2	28	.0194	15.5	3	.0262	21.0
77	.0062	5.0	52	.0130	10.4	27	.0197	15.8	2	.0265	21.2
76	.0065	5.2	51	.0132	10.6	26	.0200	16.0	1	.0267	21.4
									0	.0270	21.6

Annex 1, Table 6

Table 6.--Example of differences between ΔE_a, based on formula [2] and ΔE_i, based on formula [3]: For 14 CIE test samples under Standard Warm White fluorescent lamp

Test sample identification			Test Lamp: 3000°K Standard W.W. fluorescent # Reference Lamp: 3000°K Planckian		
CIE no.	Munsell notation		ΔE_a	ΔE_i	Difference $\Delta E_a - \Delta E_i$
1	7.5R	6/4	11.6	11.9	+0.3
2	5Y	6/4	6.3	6.3	0.0
3	5GY	6/8	1.2	2.0	+0.8
4	2.5G	6/6	13.4	13.0	-0.4
5	10BG	6/4	12.6	12.6	0.0
6	5PB	6/8	10.7	10.0	-0.7
7	2.5P	6/8	7.0	7.1	+0.1
8	10P	6/8	16.7	18.4	+1.7
Average			9.9	10.1	0.5
9	4.5R	4/13	42.6	44.6	+2.0
10	5Y	8/10	10.7	14.5	+3.8
11	4.5G	5/8	19.7	17.1	-2.6
12	5PB	3/11	32.0	16.8	-15.2
13	5YR	8/4	8.6	11.0	+2.4
14	5GY	4/4	1.1	1.3	+0.2
Average			20.2	17.6	4.6

COMMERCIAL LAMP.

Note: Average differences between formulas are relatively small for samples 1-8 used in the General Index, but are large for samples 9-14. Samples 1-8 were selected so that formula [2] can be applied with confidence that a lamp will receive a general rating essentially the same whether or not differences in luminous reflectance are included. In the above case of a Standard Warm White fluorescent lamp, the colour rendering index, R_a, is 54 when based on $\overline{\Delta E_a}$ computed from formula [1], and R_i is 53 when based on $\overline{\Delta E_i}$ computed from formula [1_a], a difference that is not significant.

Cotton, AMS, USDA - July 1962
Prepared for office use,
Standardization Section,
Standards and Testing Branch,
by Josephine J. Tomaszewski

1961 GRADE SURVEYS OF AMERICAN UPLAND AND AMERICAN EGYPTIAN COTTONS[1]

Analysis and Summary for Color and Trash

Contents

During the 1961-62 season two types of grade surveys were made under CN Instruction 910-3; one that required biweekly collection of samples of every grade of upland and American Egyptian cottons classed in the crop. These were for measurement of color and trash in the laboratory. The other consisted of a grade-box survey that required a set of grade boxes of upland cotton be prepared in each of 29 regular classing offices, with 3 offices saving additional samples of American Egyptian cottons.

1. Laboratory Survey of Upland Cottons

The laboratory followed a new procedure in 1961 by having samples measured at College Station and Clemson instead of Washington. From the beginning of the season, and continuing through February, it was required that three

---

[1] For comparison with similar data for 1951-1958 crops, see summary charts contained in COTTON GRADE STUDIES, Reports No. 2 (Color Surveys) and No. 3 (Trash and Color) by Nickerson and Tomaszewski, May 1959, prepared for use at 1959 Universal Grade Standards Conference.

Form 1 samples be selected every two weeks of typical upland cottons classed in each grade (including Plus, Light Spotted, and Light Gray) from 39 classing offices (seasonal offices included). Samples from the Southeast and South Central Areas were sent to Clemson, those from the Southwest and West to College Station, where color measurements and Shirley Analyzer tests were made. All samples were measured for color, with instructions that at least 10 percent were to be measured for trash on the Shirley Analyzer. Color diagrams and trash data sheets resulting from these measurements were sent to Washington where they were combined for analysis. Summary charts and tables were kept current for each office by grade, and by area. For each office, these results with those of previous years, by dates and by grades, are filed in the color laboratory.

For the many thousands of samples measured in this survey, figure 1 shows the average color of cotton classed in White, Light Spotted, Spotted, Tinged, and Yellow Stained for all four areas. Figures 2 to 4 indicate the range of color for each of these grades as classed in four areas, figure 2 for White, Spotted, and Tinged grades, figure 3 for Plus and Gray grades, and figure 4 for Light Gray and Light Spotted grades.

Figure 5 shows the average color improvement by grades, for each area and the United States, after samples were cleaned on the Shirley Analyzer. (All lines in each grade group are to be considered as originating at the center of each grade group.) Figure 6 shows the color of individual typical samples from the Southwestern Area before-and-after they were cleaned on the Shirley Analyzer. Compared with results for 1951-53, and 1958, the amount of color improvement in 1961 seems closer to that of 1951-53 than to 1958 (see figures 9-12 of 1959 No. 3[1] report on trash and color).

Figure 7 shows the average of nonlint in 1961 for the United States, and for four areas, against the 1953 standards. This chart indicates how much less Shirley Analyzer trash there is in the 1961 grades compared to the 1953 standards. The data support the consistently lower level of trash in relation to color that has been increasingly evident in the past several crops.

Table 1 contains data for average color change and percent Shirley Analyzer for the four areas in the United States for 4,410 trash samples (1 of every 3 color samples). Table 2 contains data representing the color change and percent Shirley Analyzer for each classing office in the four areas for all grades classed, grouped according to grade-color classification.

2. Classification Survey of Upland Cottons

Approximately 5,500 samples, put up in sets of grade survey boxes at the several classing offices, were sent to Washington for measurement and classification review. The average color of these cottons, as they were put up to represent each grade of White, Light Spotted, Spotted, and Tinged cottons, are shown in figure 8.

3. Comparison of Surveys to Each Other and to the Grade Standards

While a comparison of figure 8 to figure 1 indicates a general similarity of results for the two surveys, there is somewhat more regularity in the color spacing of the box-survey samples. The principal difference seems to be that the high grades of Light Spotted average more yellow, and more nearly on the correct standards level, for samples in the box survey. Averages for the sample survey are significantly whiter for the higher grades of Light Spotted than for previous years. See figure 9, on which the 1961 average color for Light Spotted is plotted against similar measurements for the 1951-58 crops.

Classification levels for the laboratory survey are not as close to the standards as for the box survey. For example, only Middling is well centered for color, and even that grade is whiter than in previous years (e.g., compare results with figure 1 of the 1959 report on color surveys).

In the laboratory survey the higher Light Spotted grades are classed easier than required to equal the color level of the standards, e.g., in figure 1, SM Light Spotted is close to Middling, while GM Light Spotted is closer to SM than GM. In the White cottons the high grades and low grades all tend to center toward Middling by one-half or one full grade. While the classification survey results in grades more nearly on the standards level than the laboratory survey, nevertheless in the higher grades the White cottons average much whiter than the average of cottons required for use in the standards boxes, and much whiter than classed in surveys of previous years. This shift is marked.

Both surveys confirm for 1961 the continued change in relationship of color and trash that finds considerably less trash in all grades of upland cottons than in earlier years (information used to substantiate the change in standards proposed to the 1962 Grade Standards Conference).

Other important information shown by these surveys concerns differences in levels of classing results, both when the surveys are compared to each other and to the standards. There is, for example, more regularity in color spacing of grades in the box survey than in the survey samples sent to the laboratories. Averages for color of grades in the box survey were closer to averages of the grade standards than were the average of samples in the laboratory survey. Agreement with standards was best for both surveys at the levels of Middling White, SLM Light Spotted, SLM Spotted, and LM Tinged grades. Grades higher and lower than these depart increasingly from the average color of standards for these grades, the laboratory-survey samples

more than box-survey samples. For the White grades the levels of color for the laboratory survey show GM a full color grade too low, SM one-half a grade low, Middling O.K., SLM a quarter grade high, LM a half grade high, SGO three-quarters of a grade too high, and GO averaging almost a full grade higher than the standard.

Average colors of White grades from different areas cluster close to a common average that is whiter than in earlier years. As already pointed out, the 1961 averages are nearer to the whiteness expected for Western cottons than for the creamier Southwestern cottons which have provided a wide range of chroma in grades of earlier years.

The maximum differences between average color of samples and standards occurs in the laboratory-survey samples for the higher grades of Light Spotted. Cottons classed Light Spotted average whiter in color than in previous years, and the percentage of Light Spotted is higher than in any previous year. In 1961, 28.8% of the crop was classed in the Spotted categories, almost twice as much as in the 14.3% average for the 7 years prior to 1957 when Light Spotted was made a separate category. For this comparison, see figure 10.

In the laboratory survey, GM Light Spotted Southwestern bales average a color that is on the low side of SM, between positions 5 and 6 in the purchase guide (figure 11) for White Standards. By a similar comparison, the SM Light Spotted Southwestern bales average a color on the high side of Middling, just above the guide color for bale position 5. Middling Light Spotted Southwestern bales average on the low side of Middling color, about at the limit of the guide color for the bale in position 6. At the level of SLM Light Spotted, the average color was close to that required by the standards. The LM Light Spotted average color averaged higher than the LM level, but about equal the standards requirement for degree of yellowness.

4. Grade Surveys of American Egyptian Cottons

Samples for both surveys of American Egyptian cottons were collected in a similar manner except that for one survey they were sent biweekly to College Station for color and trash measurements, and for the other they were saved weekly and sent at the end of the season to Washington for classification and color measurement. Since the method of collection was similar, and there were such a limited number of samples in each survey, color measurements for both surveys have been combined in plotting the ranges, but are shown separately for average grade color. Figure 12 shows average color for grades classed in El Paso, Phoenix, and Pecos, for both laboratory and classification surveys. Samples in the classification survey were held in storage long enough before measurement so that they were more yellow than those measured as they were currently received at College Station. Figure 13 shows the color range by grades, as classed in each office.

Figure 14 shows average Shirley Analyzer nonlint for grades of American Egyptian cottons classed in El Paso, Phoenix, and Pecos in relation to the level of nonlint shown by a curve representing the grade standards. Results show that for the higher grades, the nonlint content in 1961 cottons is close to that of the standards, but that cottons classed in the lower grades are better in trash and color than in the standards.

Figure 15 illustrates the average color improvement after cleaning on the Shirley Analyzer for each of the grades, by offices. Except for a few samples classed grade 9 in Phoenix, the color improvement by trash removal shows a very narrow range for cleaned lint color. This is emphasized in figure 16 which demonstrates that most of the cleaned color is equal to grade 4, and above, the only exception being three samples from Phoenix equal to 5.

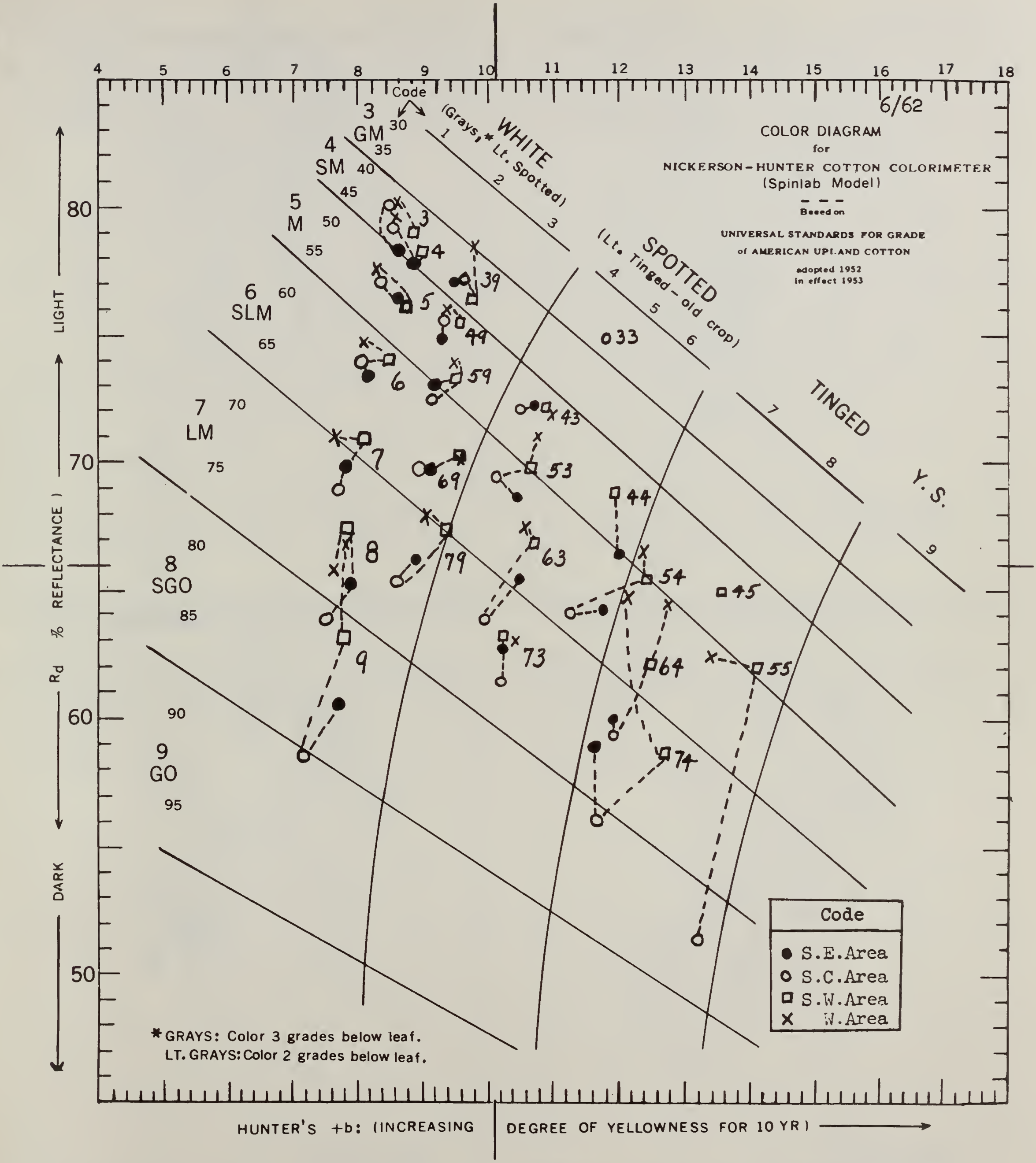


FIGURE 1.--1961-62 COLOR-TRASH SURVEY: Average color of cotton classed in White, Light Spotted, Spotted, Tinged, and Yellow Stained grades for four areas.

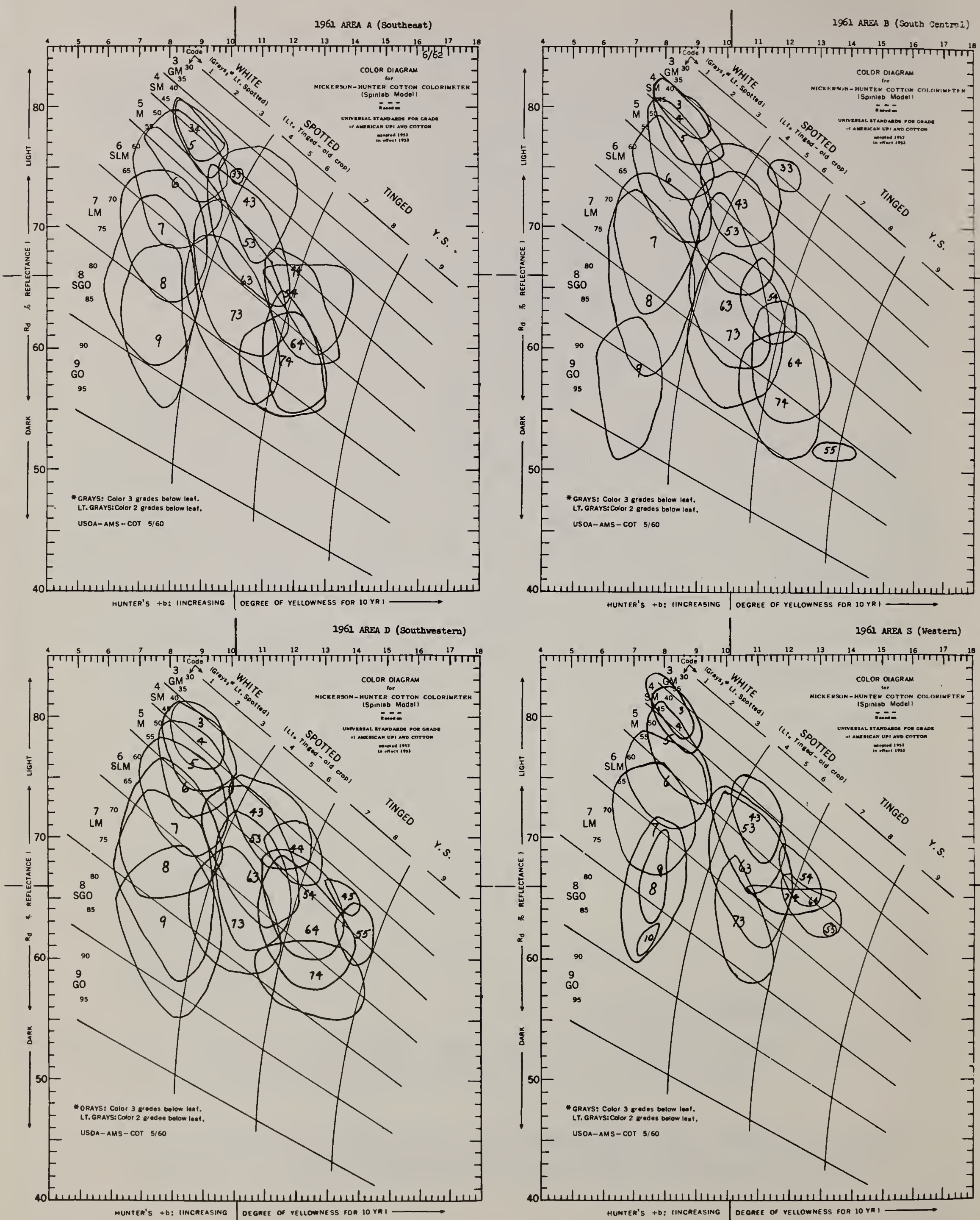


FIGURE 2.--1961 COLOR-TRASH SURVEY: Range of color in White, Spotted, Tinged, and Yellow Stained grades for four areas.

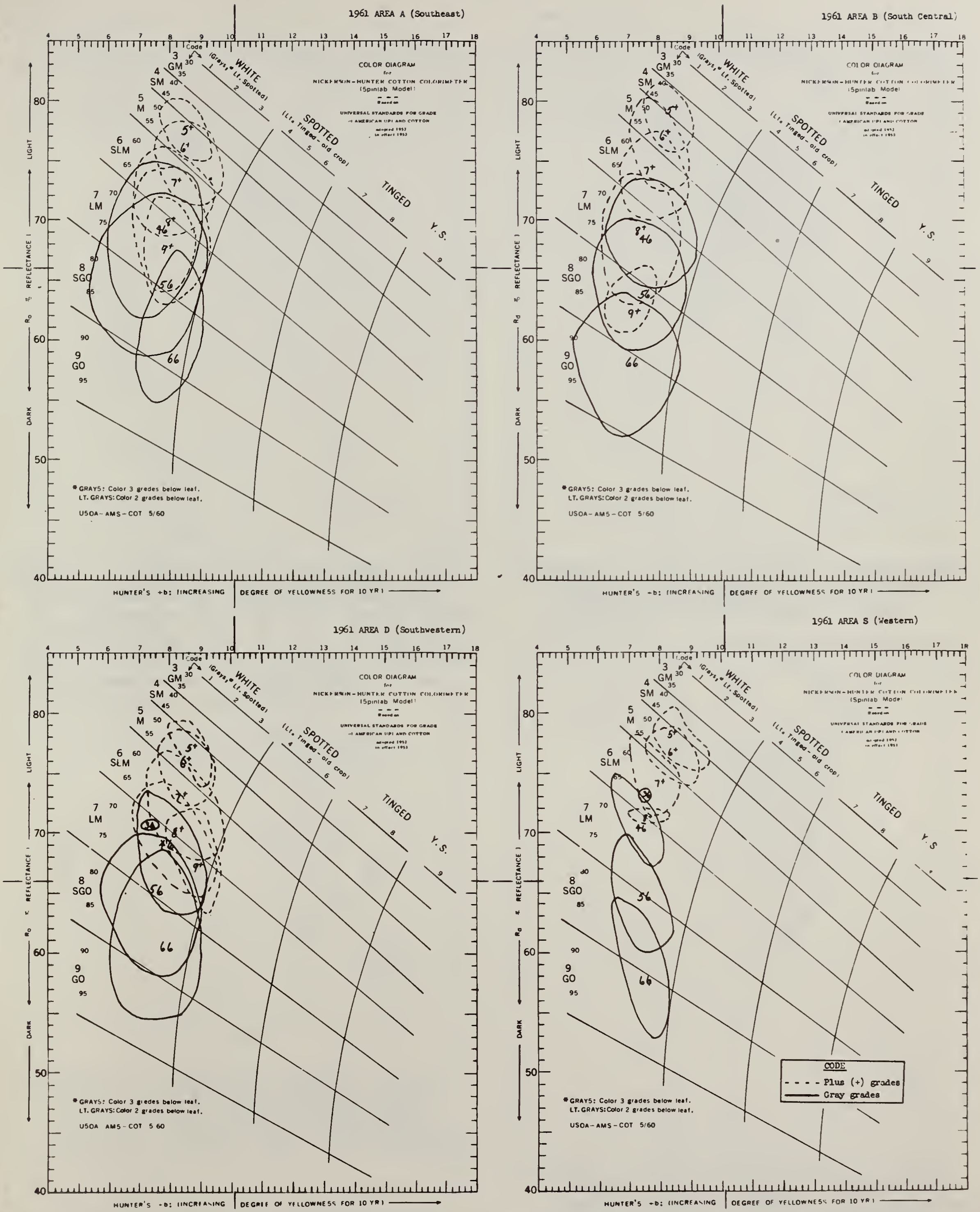


FIGURE 3.--1961 COLOR-TRASH SURVEY: Range of color in Plus (+) and Gray grades for four areas.

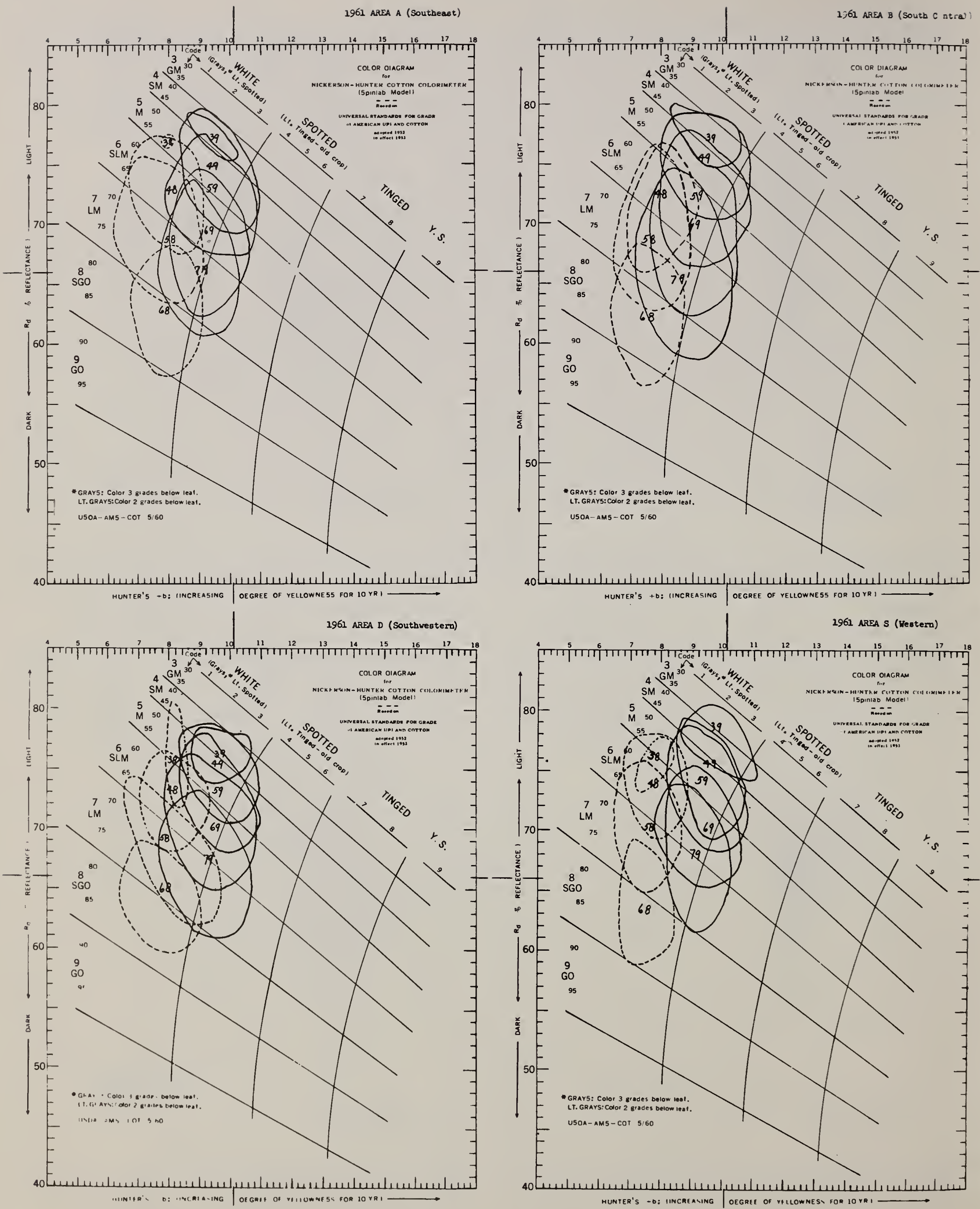


FIGURE 4.--1961 COLOR-TRASH SURVEY: Range of color in Light Gray and Light Spotted grades for four areas.

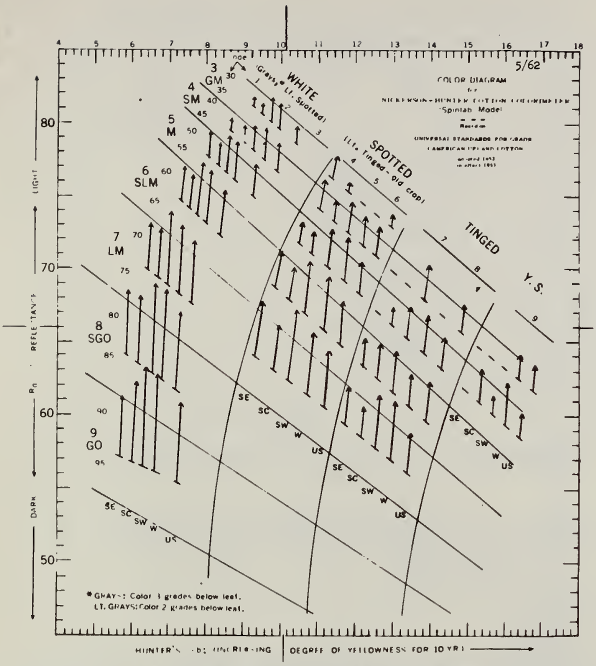


FIGURE 5.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AFTER CLEANING ON THE SHIRLEY ANALYZER, for cottons in the 1961 COLOR-TRASH SURVEY, from four areas (SE, SC, SW, W) and the entire United States. (The ΔR_d lines are to be considered as originating at the center of each grade group.)

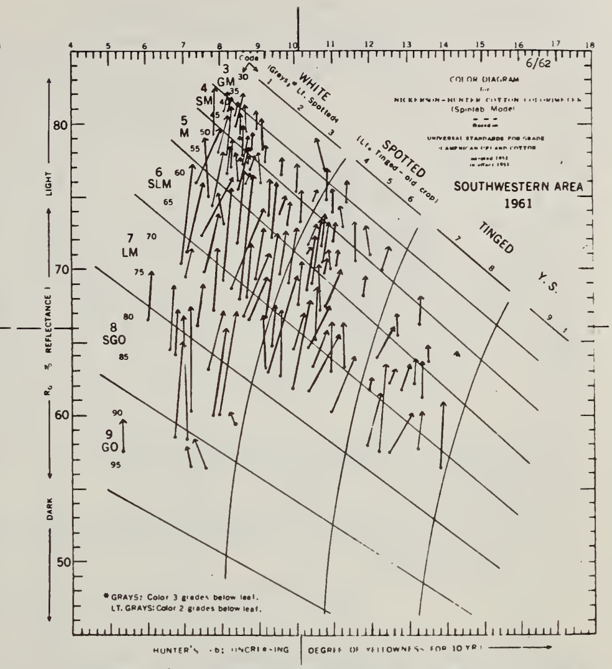


FIGURE 6.--COLOR OF TYPICAL SAMPLES FROM THE 1961 CROP BEFORE (•) AND AFTER (^) CLEANING ON THE SHIRLEY ANALYZER.

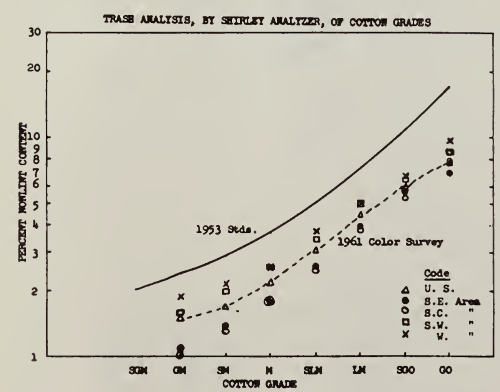


FIGURE 7.--AVERAGE OF NONLINT IN THE 1961-62 COLOR-TRASH SURVEY FOR THE UNITED STATES AND FOUR AREAS SHOWN AGAINST A CURVE OF THE 1953 STANDARDS.

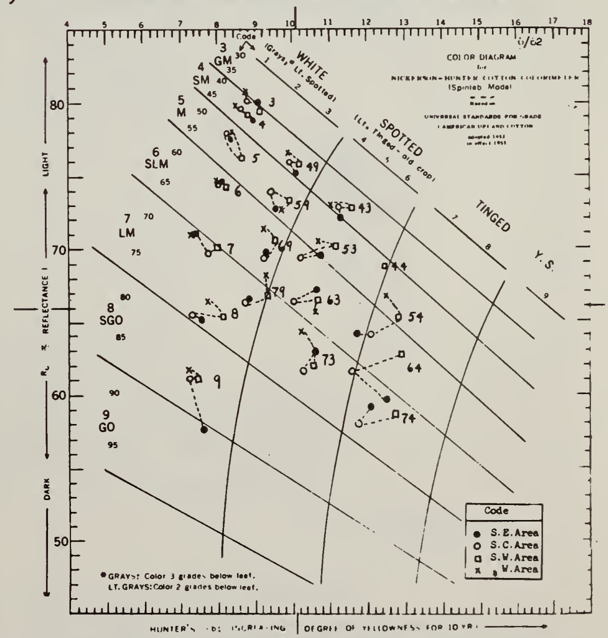


FIGURE 8.--1961-62 GRADE SURVEY BOXES: Average color of typical samples of cotton classed in White, Light Spotted, and Tinged grades. (CN Instruction No. 910-3, III)

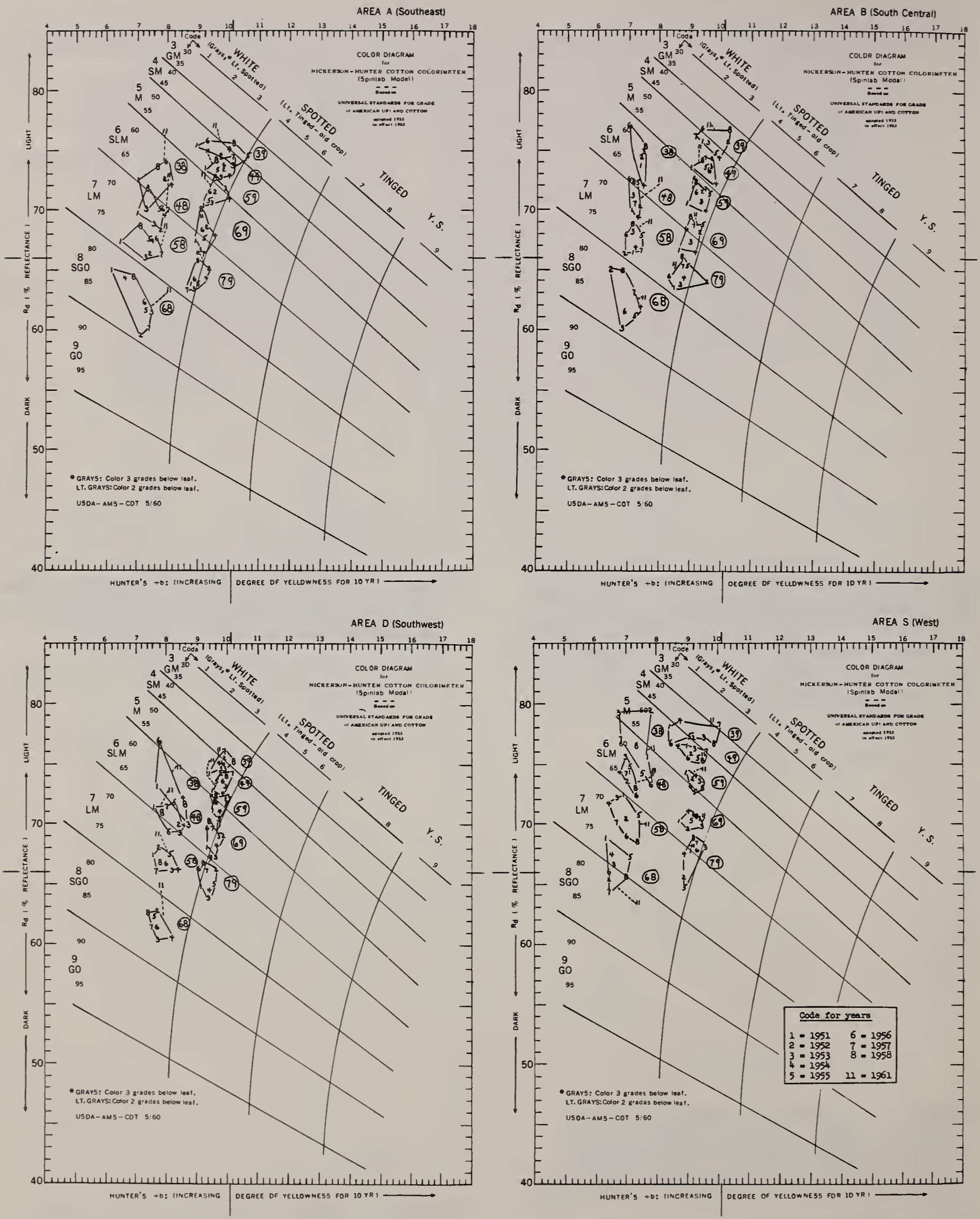


Figure 9.--Average color of cotton classed in Light Gray and Light Spotted grades, by years for four areas.

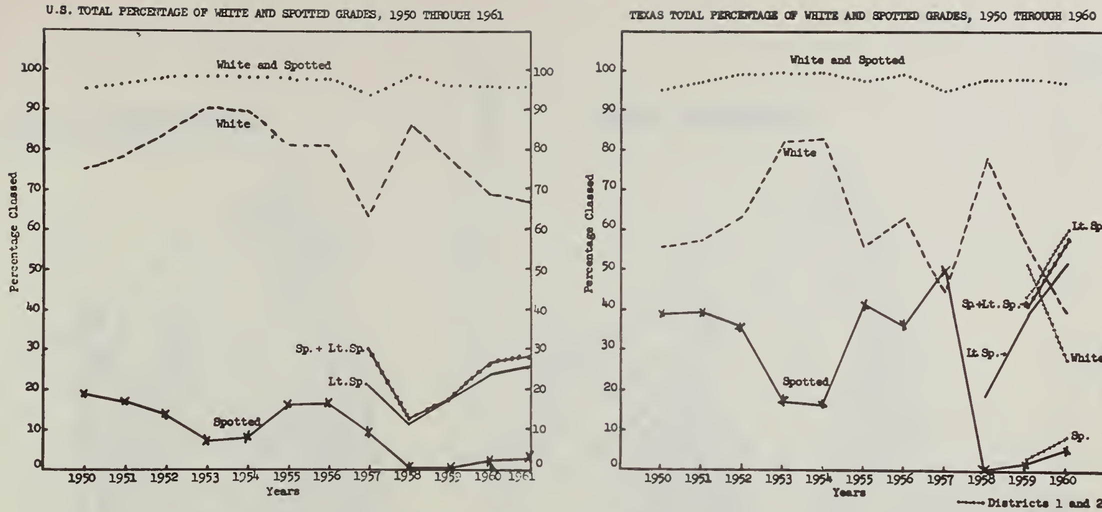


Figure 10.--Comparative data for White and Spotted grades, 1950 through 1960, for the U. S. and Texas (Districts 1 and 2).

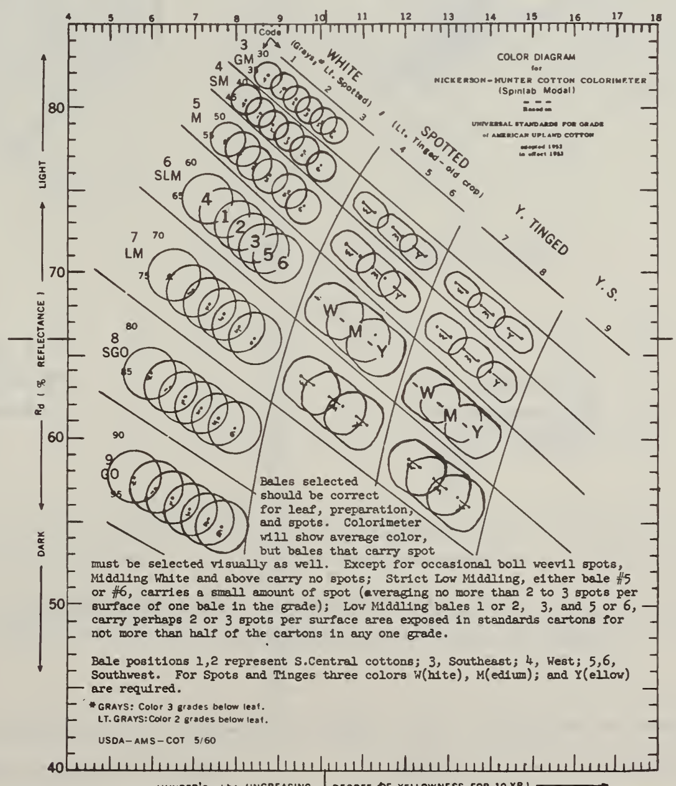


FIGURE 11.--GUIDE FOR PURCHASE OF BALES FOR GRADE STANDARDS. Circles and ellipses represent color wanted. Numbers in White grade circles refer to bale positions in grade boxes. (In 6-sample box, bale positions in box are numbered 1 to 6, upper left corner to lower right; in 12-sample box, duplicate samples of 1 to 6 are placed in order, upper left to lower right.)

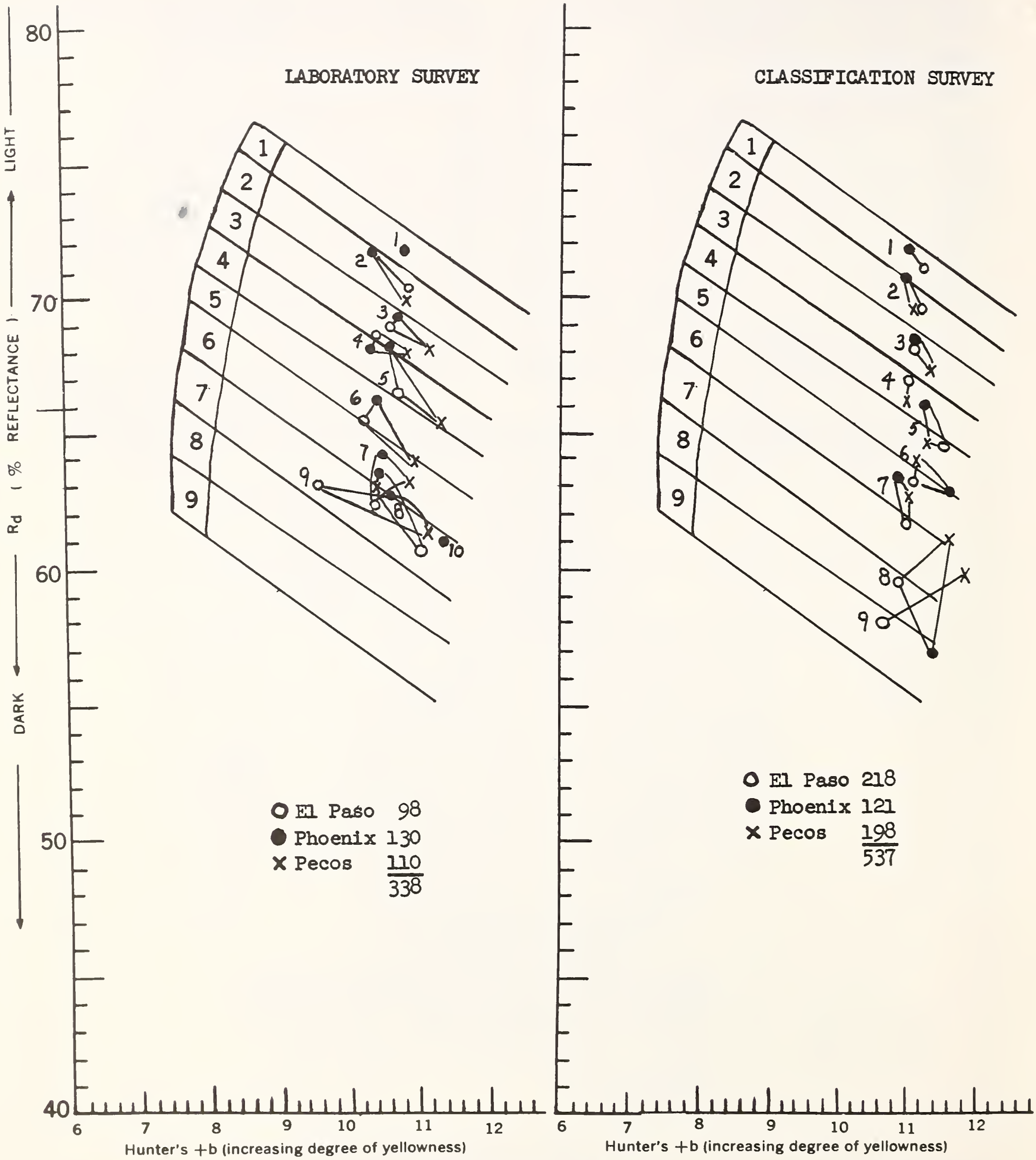
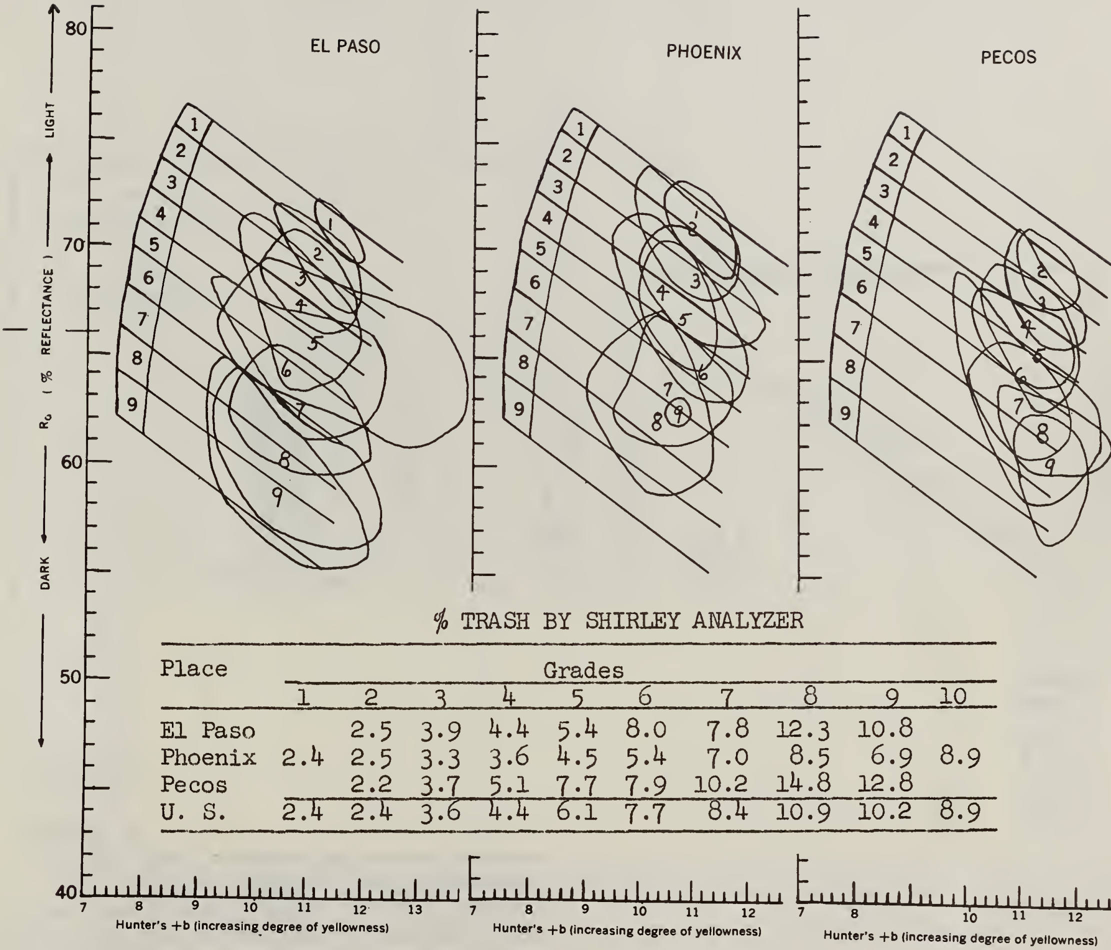


FIGURE 12.--1961 AMERICAN EGYPTIAN SURVEY: Average Color of American Egyptian grades classed in El Paso, Phoenix, and Pecos, for laboratory and classification surveys.



% TRASH BY SHIRLEY ANALYZER

Place	Grades									
	1	2	3	4	5	6	7	8	9	10
El Paso		2.5	3.9	4.4	5.4	8.0	7.8	12.3	10.8	
Phoenix	2.4	2.5	3.3	3.6	4.5	5.4	7.0	8.5	6.9	8.9
Pecos		2.2	3.7	5.1	7.7	7.9	10.2	14.8	12.8	
U. S.	2.4	2.4	3.6	4.4	6.1	7.7	8.4	10.9	10.2	8.9

FIGURE 13.--1961 AMERICAN EGYPTIAN SURVEY: Range of color of American Egyptian cottons classed in El Paso, Phoenix, and Pecos, by grades.

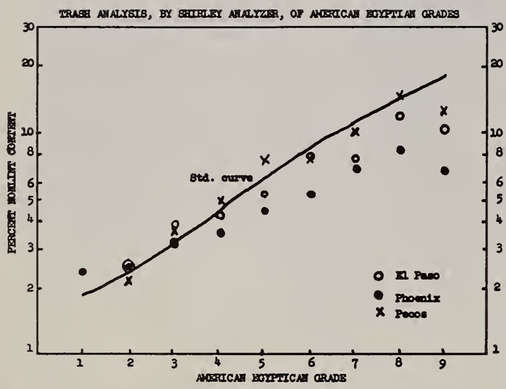


FIGURE 14.--1961 AMERICAN EGYPTIAN SURVEY: Average of nonlint of American Egyptian cottons from El Paso, Phoenix, and Pecos shown in relation to the curve for nonlint in the standards.

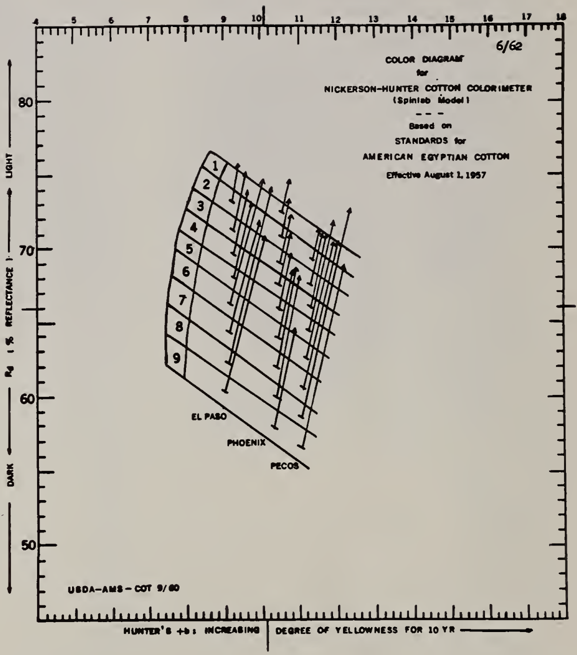
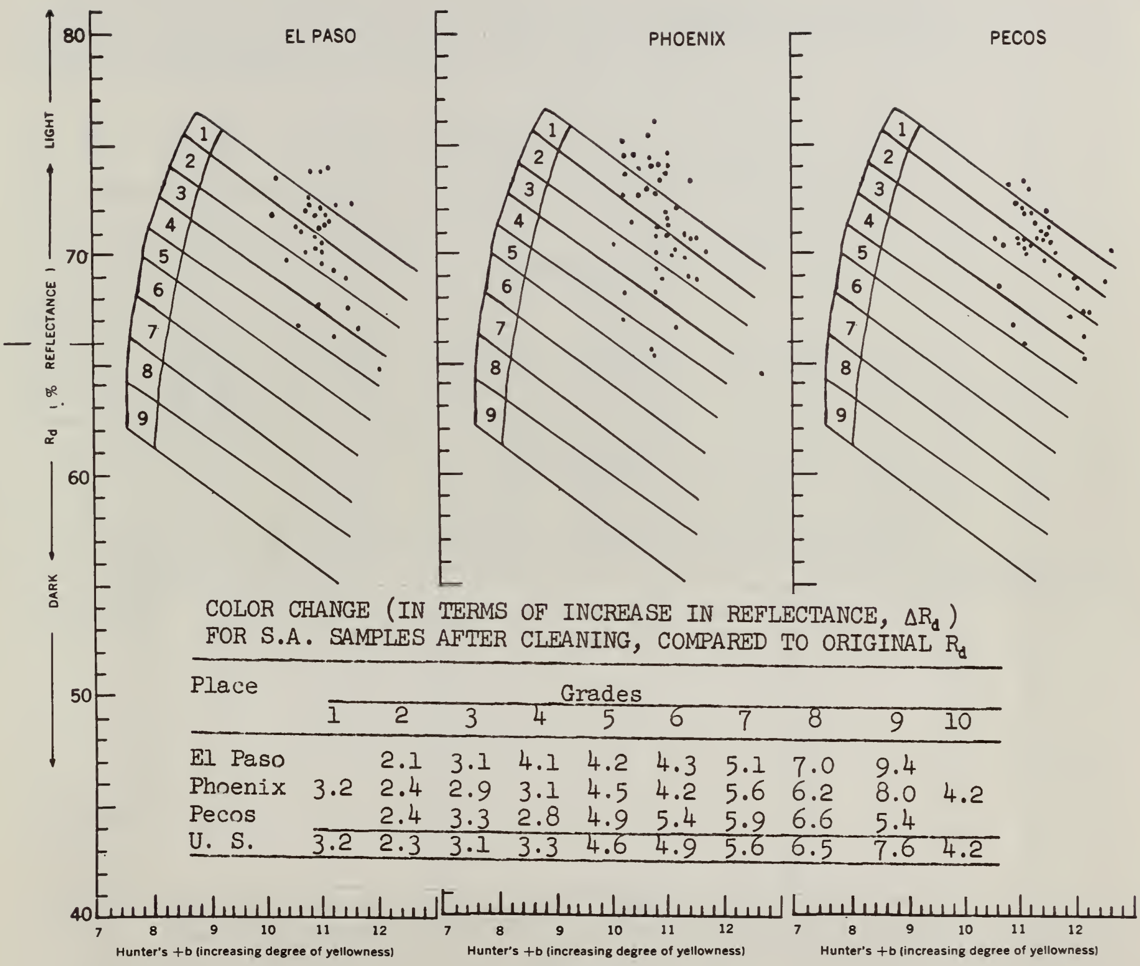


FIGURE 15.--1961 AMERICAN EGYPTIAN SURVEY: Average color improvement (ΔR_d) after cleaning on the Shirley Analyzer, for cottons from El Paso, Phoenix, and Pecos. (For purposes of comparison all ΔR_d vectors are to be considered as originating at the center of each grade.)



COLOR CHANGE (IN TERMS OF INCREASE IN REFLECTANCE, ΔR_d)
FOR S.A. SAMPLES AFTER CLEANING, COMPARED TO ORIGINAL R_d

Place	Grades									
	1	2	3	4	5	6	7	8	9	10
El Paso		2.1	3.1	4.1	4.2	4.3	5.1	7.0	9.4	
Phoenix	3.2	2.4	2.9	3.1	4.5	4.2	5.6	6.2	8.0	4.2
Pecos		2.4	3.3	2.8	4.9	5.4	5.9	6.6	5.4	
U. S.	3.2	2.3	3.1	3.3	4.6	4.9	5.6	6.5	7.6	4.2

FIGURE 16.--1961 AMERICAN EGYPTIAN SURVEY: Range of cleaned lint color (after cleaning on the Shirley Analyzer) of American Egyptian cottons from El Paso, Phoenix, and Pecos.

TABLE 1.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for four areas in the United States for all grades classed in the 1961-62 Color-Trash Survey, a total of 4410 samples

AREAS	GRADES 3		4		5		6		7		8		9	
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA
					a. WHITE									
A	0.6	1.1	0.9	1.4	1.7	1.8	2.4	2.6	3.2	4.0	4.5	5.8	4.2	7.0
B	0.7	1.0	1.0	1.3	1.5	1.8	2.3	2.5	3.3	3.8	4.6	5.4	5.5	8.0
D	1.6	1.6	1.6	2.0	2.5	2.6	3.7	3.5	5.0	5.1	6.2	6.6	6.7	8.6
S	1.6	1.9	2.1	2.2	2.7	2.6	3.6	3.8	4.7	5.1	6.3	6.8	6.7	9.9
Av. U.S.	1.3	1.5	1.4	1.7	2.2	2.2	3.1	3.1	4.1	4.5	5.3	6.1	5.4	7.9
					b: PLUS GRADES									
A					1.5	1.7	2.3	2.5	3.2	3.7	4.4	5.3	4.2	8.1
B					1.4	1.7	2.2	2.5	3.3	3.6	5.6	6.4	7.1	9.9
D					2.3	2.3	3.4	3.2	4.9	4.7	6.5	6.6	8.4	8.3
S					2.7	2.5	3.7	3.4	4.9	5.1	1.8	5.0	--	--
Av. U.S.					1.9	2.0	2.8	2.9	4.2	4.2	5.6	6.2	7.0	8.8
					c: LIGHT SPOTTED									
A	1.8	1.7	1.3	1.9	2.2	2.5	2.6	3.3	3.0	4.7				
B	1.3	1.4	1.2	1.5	1.6	2.2	2.3	2.9	3.5	4.2				
D	1.4	1.8	1.8	2.3	2.4	2.9	3.6	4.1	5.0	6.1				
S	1.7	2.3	2.3	2.7	2.9	3.3	4.2	4.5	4.8	6.2				
Av. U.S.	1.5	1.8	1.7	2.1	2.3	2.7	3.2	3.7	4.1	5.2				
					d: SPOTTED									
A	1.6	1.5	2.1	1.8	1.5	2.5	2.5	3.6	3.8	5.6				
B	0.4	1.4	1.4	1.6	1.5	2.2	2.3	3.2	3.1	4.5				
D			2.1	2.6	2.6	3.4	3.6	4.6	5.0	6.3				
S			2.4	2.6	2.9	3.6	3.5	4.6	4.4	7.1				
Av. U.S.	0.6	1.4	2.0	2.2	2.2	3.0	3.0	4.0	3.9	5.6				
					e: TINGED				AND		4 YSTAINED		5 YSTAINED	
A			0.8	1.6	3.0	2.7	2.3	3.4	2.6	4.4				
B			--	--	1.3	2.4	2.6	3.3	2.3	4.9			2.3	4.4
D			2.4	2.7	2.1	3.3	3.0	4.9	3.7	6.6	1.7	3.5	1.1	4.0
S			--	--	2.5	4.1	2.1	6.6	4.0	3.4			2.8	4.0
Av. U.S.			1.8	2.3	2.2	3.1	2.7	4.3	2.8	5.5	1.7	3.5	1.5	4.2
					f: LIGHT GRAY									
A	2.4	1.5	1.7	1.7	2.1	2.6	2.5	3.9						
B	--	--	1.7	1.7	2.4	2.3	3.3	3.3						
D	2.6	1.9	2.3	2.4	2.7	2.9	4.1	4.1						
S	2.4	2.3	2.8	2.7	3.3	3.5	4.2	4.3						
Av. U.S.	2.5	2.0	2.1	2.1	2.6	2.7	3.3	3.8						
					g: GRAY						BELOW 66			
A			1.4	1.9	1.9	2.7	2.3	3.7			2.9	4.2		
B			1.8	1.7	2.3	2.5	2.6	3.3						
D	3.8	2.2	2.0	2.1	3.2	3.3	2.4	4.3						
S	1.3	3.0	3.3	2.9	3.0	4.0	4.5	5.2						
Av. U.S.	2.6	2.6	1.4	1.6	2.5	2.9	2.7	3.8			2.9	4.2		

TABLE 2a.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: a. White grades

* LOCATION	GRADES 3		4		5		6		7		8		9 **	
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA
A - 1	0	1.0	0.9	1.5	1.7	2.0	3.0	2.7	4.9	5.4	5.4	5.8	3.1	9.4 **
2	0.7	1.0	0.9	1.0	1.8	1.6	2.0	2.3	2.9	3.7	4.1	4.7	5.2	8.6
3	--	--	1.2	1.4	1.7	1.9	1.3	2.7	2.3	3.9	5.1	6.4	3.6	5.8
4	--	--	0.8	1.4	1.3	1.9	2.4	2.9	2.2	3.9	3.4	5.2	2.4	6.4
5	--	--	1.0	1.5	1.6	1.7	3.0	2.5	4.2	3.9	5.3	7.2	4.6	6.0
8	--	--	0.7	1.4	1.3	1.6	2.6	2.4	2.7	3.6	3.7	4.9	4.9	7.3
9	0	1.4	2.0	1.9	1.9	1.9	2.7	3.1	3.1	4.5	4.0	5.6	3.5	7.0
10	1.4	1.3	0.2	1.2	2.4	2.0	2.0	2.5	3.1	3.7	4.9	5.2	4.6	5.1
AV. AREA	0.6	1.1	0.9	1.4	1.7	1.8	2.4	2.6	3.2	4.0	4.5	5.8	4.2	7.0
B - 1	0.8	1.2	1.3	1.5	1.8	1.4	2.8	2.3	2.8	3.3	4.9	4.6	--	--
2	0.1	1.0	0.8	1.2	0.7	1.6	2.0	2.7	3.2	4.0	4.6	5.7	5.7	6.8
3	1.2	0.8	1.1	1.1	1.3	1.9	2.0	2.8	3.5	3.6	4.9	6.2	--	--
4	0.9	0.8	1.5	1.4	1.5	1.9	2.7	2.8	3.2	3.5	4.1	5.1	--	--
5	1.0	0.9	1.1	1.2	1.4	2.2	2.1	2.6	3.0	3.7	4.7	5.8	5.2	7.8
6	0.2	1.0	1.2	1.2	2.0	1.8	2.9	2.4	4.3	4.2	5.3	6.5	7.6	12.2
10	0	0.8	1.0	1.4	2.3	2.1	2.1	2.8	3.1	4.4	4.8	5.7	8.4	13.6
11	1.5	1.2	1.2	1.1	1.3	1.6	3.1	2.3	4.0	3.6	3.9	4.6	4.5	6.2
12	--	--	0.3	1.3	2.3	1.8	2.4	2.6	--	--	4.6	4.4	--	--
13	--	--	1.1	1.5	1.1	1.7	2.1	2.5	2.4	3.2	--	--	--	--
14	--	--	-0.3	1.0	2.0	2.0	2.8	2.5	--	--	--	--	--	--
AV. AREA	0.7	1.0	1.0	1.3	1.5	1.8	2.3	2.5	3.3	3.8	4.6	5.4	5.5	8.0
D - 1	2.0	1.3	1.5	2.3	2.8	2.9	3.8	3.4	5.3	5.2	7.9	7.3	8.4	8.6
2	--	--	1.7	2.0	2.6	2.3	4.1	3.4	6.4	5.5	6.9	7.2	--	--
3	1.8	1.5	1.8	1.9	2.7	2.3	4.2	3.2	5.4	4.9	4.1	6.0	5.6	12.6
4	2.2	1.7	2.4	2.0	2.2	2.0	4.0	3.8	4.0	5.0	6.9	5.7	--	--
5	--	--	1.7	1.7	2.8	2.4	5.0	4.2	5.5	5.2	6.8	6.7	6.0	11.3
7	2.6	3.1	1.5	2.0	2.2	2.6	2.7	3.0	4.8	5.3	6.1	6.4	--	--
8	1.6	1.8	1.3	2.0	2.2	2.6	3.4	3.4	5.1	5.0	5.1	6.0	8.6	10.3
10	2.1	1.4	1.5	2.0	2.8	2.4	2.9	3.0	3.8	4.8	4.8	5.6	5.1	6.1
11	--	--	1.6	2.0	2.6	2.4	3.3	2.7	4.4	4.3	--	--	--	--
12	1.0	1.8	1.2	2.0	1.9	2.2	3.0	3.2	3.4	4.6	4.9	6.7	9.0	6.4
13	1.4	1.4	1.5	1.9	2.5	2.6	3.2	3.6	5.2	5.0	7.4	7.2	--	--
14	1.6	1.3	1.2	1.9	2.5	2.4	3.0	3.6	4.0	5.0	4.1	5.9	4.2	7.0
15	1.0	3.3	1.9	2.4	2.6	3.3	4.2	4.4	5.0	5.3	6.8	7.7	8.6	10.9
AV. AREA	1.6	1.6	1.6	2.0	2.5	2.6	3.7	3.5	5.0	5.1	6.2	6.6	6.7	8.6
S - 1	1.3	2.0	1.9	2.1	2.3	2.5	3.2	4.0	3.9	4.2	6.0	6.4	--	--
2	1.7	1.7	2.3	2.1	2.7	2.7	2.8	3.9	5.2	5.9	7.7	10.0	--	--
3	1.6	1.9	2.1	2.2	2.5	2.7	3.5	3.7	5.9	4.5	5.5	4.4	--	--
5	1.7	2.3	1.9	2.0	3.0	2.8	3.6	3.6	3.7	3.8	5.5	5.8	--	--
6	1.4	1.9	2.0	2.8	2.8	2.7	3.4	4.0	3.6	5.0	6.0	7.6	7.8	9.0
7	1.7	1.7	2.1	2.1	2.9	2.6	4.2	3.4	5.4	5.4	9.2	4.3	--	--
8	1.8	1.6	2.1	2.0	2.7	2.5	4.0	4.3	3.7	5.0	7.1	9.1	6.2	10.3
AV. AREA	1.6	1.9	2.1	2.2	2.7	2.6	3.6	3.8	4.7	5.1	6.3	6.8	6.7	9.9

* A:1, Atlanta; 2, Birmingham; 3, Columbia; 4, Montgomery; 5, Raleigh; 8, Augusta; 9, Moultrie; 10, Vienna.
B:1, Alexandria; 2, Greenwood; 3, Hayti; 4, Jackson; 5, Little Rock; 6, Memphis; 10, Blytheville; 11, Winnsboro; 12, Hattiesburg; 13, Prentiss; 14, Opelousas.
D:1, Altus; 2, Okla. City; 3, Austin; 4, Corpus Christi; 5, Dallas; 7, Lubbock; 8, Abilene; 10, Harlingen; 11, Waco; 12, Lamesa; 13, Munday; 14, Brownfield; 15, Memphis, Texas.
S:1, Bakersfield; 2, El Paso; 3, Phoenix; 5, Fresno; 6, Carlsbad; 7, El Centro; 8, Pecos.

** Below Grade White, Location 8: 1 sample, ΔR_d = 2.2; %SA = 7.8.

TABLE 2b.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: b. Plus (+) grades

LOCATION	GRADES 5+ ΔR_d	5+ %SA	6 + ΔR_d	6 + %SA	7+ ΔR_d	7+ %SA	8+ ΔR_d	8+ %SA	9 + ΔR_d	9 + %SA
A - 1	2.2	2.0	3.1	2.5	3.6	3.9	4.6	6.3	3.4	7.6
2	1.1	1.3	1.9	2.3	2.8	2.8	4.1	4.2	3.0	6.4
3	2.2	1.8	2.3	2.2	3.3	3.7	5.4	5.3	--	--
4	--	--	1.7	2.9	2.7	4.3	3.6	5.2	4.6	9.2
5	1.3	2.0	2.7	2.4	3.5	4.0	4.5	5.4	--	--
8	1.8	2.1	2.5	2.3	3.2	4.2	4.4	5.8	6.0	9.2
9	1.8	1.8	2.1	3.8	3.1	3.4	4.9	7.2	--	--
10	0.9	1.6	2.4	2.4	4.0	3.3	4.4	4.2	--	--
Av. AREA	1.5	1.7	2.3	2.5	3.2	3.7	4.4	5.3	4.2	8.1
B - 1	1.2	1.7	2.3	2.4	2.9	3.2	5.6	5.9	9.2	8.0
2	1.0	1.8	2.3	2.7	2.6	3.6	5.8	7.1	8.6	13.6
3	1.2	1.7	2.6	2.5	3.5	3.6	4.0	7.0	--	--
4	1.6	1.6	1.7	2.5	3.4	3.4	4.5	4.1	--	--
5	2.0	1.6	2.3	2.9	3.4	4.0	5.9	7.2	6.0	9.5
6	0.9	2.0	2.5	2.4	3.7	4.4	6.3	6.0	--	--
10	1.3	1.6	1.9	2.3	4.4	4.0	5.1	6.8	--	--
11	1.6	1.7	2.0	2.4	3.8	2.8	5.1	5.3	--	--
12	--	--	--	--	2.4	3.6	--	--	--	--
13	2.2	1.6	2.2	2.2	3.8	2.7	--	--	--	--
14	--	--	2.5	2.2	2.6	3.3	--	--	--	--
Av. AREA	1.4	1.7	2.2	2.5	3.3	3.6	5.6	6.4	7.1	9.9
D - 1	2.3	2.7	3.2	3.1	5.3	4.7	6.1	5.9	7.6	9.7
2	1.2	2.1	3.6	2.7	5.2	4.4	7.6	7.6	--	--
3	2.4	2.2	3.5	3.1	5.6	4.3	7.6	6.1	7.9	8.9
4	2.6	1.6	3.7	3.5	6.2	4.6	8.3	8.0	--	--
5	--	--	4.2	3.4	4.3	4.2	6.8	8.8	--	--
7	3.9	2.2	2.7	2.9	4.5	5.2	6.7	7.3	--	--
8	1.8	2.0	3.7	3.1	4.8	4.8	5.4	5.0	12.8	6.1
10	2.2	2.8	2.9	2.4	4.1	3.9	6.9	6.3	7.2	7.3
11	--	--	3.2	2.8	5.3	4.8	5.3	6.3	--	--
12	1.8	1.8	2.8	2.9	3.0	5.0	4.4	6.4	--	--
13	--	--	5.2	3.2	5.3	4.6	6.4	6.7	--	--
14	1.8	1.0	3.4	3.5	4.2	4.4	4.7	6.3	--	--
15	3.8	2.8	3.8	4.0	5.5	5.9	6.9	6.9	7.4	8.2
Av. AREA	2.3	2.3	3.4	3.2	4.9	4.7	6.5	6.6	8.4	8.3
S - 1	--	--	3.4	3.8	5.9	5.8	--	--	--	--
2	2.2	2.4	3.9	3.6	5.9	5.1	--	--	--	--
3	2.3	1.8	3.7	2.8	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--
6	2.0	3.6	4.6	3.8	2.3	3.6	1.8	5.0	--	--
7	2.7	2.1	3.4	2.8	--	--	--	--	--	--
8	3.4	2.9	3.3	2.5	5.0	5.2	--	--	--	--
Av. AREA	2.7	2.5	3.7	3.4	4.9	5.1	1.8	5.0	--	--

TABLE 2c.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: c. Light Spotted

LOCATION	GRADES											
	39		49		59		69		79			
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA		
A - 1	1.6	1.6	0.7	1.6	2.0	2.4	0.6	4.0	3.9	4.9		
2	--	--	1.1	1.4	2.5	1.8	2.4	2.6	2.8	3.7		
3	--	--	1.1	1.5	2.2	3.0	2.9	3.4	2.6	5.5		
4	--	--	0.8	1.9	1.9	2.1	1.8	3.4	2.8	4.5		
5	2.0	1.8	2.2	2.2	2.2	3.2	3.0	3.7	3.4	5.5		
8	--	--	0.8	2.1	1.6	2.0	1.9	3.0	2.4	4.1		
9	--	--	2.3	2.1	2.3	2.9	3.7	3.4	3.4	6.0		
10	--	--	1.6	1.8	2.2	2.1	2.7	3.1	3.5	5.3		
Av. AREA	1.8	1.7	1.3	1.9	2.2	2.5	2.6	3.3	3.0	4.7		
B - 1	2.0	1.1	1.0	1.8	1.6	1.9	2.5	2.9	3.7	3.8		
2	2.0	1.3	1.2	1.3	0.6	2.0	2.7	3.3	4.4	3.8		
3	--	--	1.4	1.9	2.4	2.4	2.8	3.0	3.2	3.9		
4	0.9	1.2	1.3	1.5	1.1	3.3	1.0	3.1	3.1	4.4		
5	1.2	1.2	1.4	1.3	1.8	1.8	1.4	2.6	4.1	4.6		
6	1.2	2.0	1.2	1.4	2.2	2.0	2.6	3.0	3.6	4.9		
10	--	--	0.2	1.2	1.5	2.8	2.9	3.4	3.5	4.8		
11	--	--	1.3	1.3	1.8	1.9	2.6	2.5	3.1	3.2		
12	--	--	3.0	2.2	0.9	2.6	--	--	2.4	4.8		
13	--	--	0.9	1.8	1.3	2.5	--	--	2.4	4.9		
14	--	--	0.8	2.1	2.5	2.2	--	--	--	--		
Av. AREA	1.3	1.4	1.2	1.5	1.6	2.2	2.3	2.9	3.5	4.2		
D - 1	2.0	1.9	1.6	2.1	2.2	2.7	3.6	4.1	5.2	5.7		
2	1.6	1.7	2.4	1.1	2.1	2.5	3.9	4.0	6.1	6.1		
3	1.7	1.7	2.3	2.3	2.7	3.0	4.2	4.3	4.7	5.0		
4	1.8	1.4	1.6	1.6	2.8	2.1	5.8	3.5	4.9	5.6		
5	--	--	1.9	2.2	2.3	3.3	3.8	3.7	5.2	6.4		
7	--	--	1.7	2.7	1.8	3.1	2.4	4.8	4.5	7.8		
8	0.7	1.7	1.2	2.2	2.5	3.2	4.0	4.4	5.8	6.0		
10	--	--	2.0	2.2	2.8	2.6	3.1	3.4	3.6	4.7		
11	1.3	2.0	1.6	2.5	3.7	2.3	2.6	4.0	5.1	7.7		
12	1.3	2.1	1.5	2.2	2.5	3.2	2.9	4.4	8.0	4.5		
13	--	--	1.6	2.4	2.6	2.6	4.0	4.0	5.0	5.7		
14	--	--	2.1	2.4	2.4	3.3	3.1	3.6	--	--		
15	--	--	1.8	2.7	2.5	3.4	4.6	5.4	5.3	6.5		
Av. AREA	1.4	1.8	1.8	2.3	2.4	2.9	3.6	4.1	5.0	6.1		
S - 1	--	--	1.6	1.6	2.9	3.5	3.5	4.3	3.7	4.8		
2	1.8	1.3	2.5	2.8	2.9	3.2	4.3	4.8	5.8	7.3		
3	--	--	1.6	2.8	3.1	3.2	4.8	4.2	5.2	6.1		
5	--	--	--	--	--	--	3.4	3.4	3.7	4.2		
6	1.9	3.0	1.9	2.7	2.5	3.6	3.9	5.2	3.5	6.9		
7	1.8	2.4	2.7	2.7	3.1	3.2	4.2	3.9	5.4	5.2		
8	1.6	2.1	2.4	2.8	2.8	3.6	4.3	5.3	6.2	8.3		
Av. AREA	1.7	2.3	2.3	2.7	2.9	3.3	4.2	4.5	4.8	6.2		

TABLE 2d.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: d. Spotted

LOCATION	33		43		53		63		73			
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA		
A - 1	--	--	1.9	2.4	2.6	2.8	3.1	4.7	2.7	6.4		
2	1.6	1.5	2.0	1.5	1.0	2.2	2.3	2.9	3.8	4.4		
3	--	--	--	--	2.4	3.2	4.0	5.0	2.0	6.1		
4	--	--	3.4	2.3	--	--	2.0	2.9	5.6	6.3		
5	--	--	2.4	2.0	1.3	2.9	2.9	4.4	4.6	8.6		
8	--	--	--	--	1.3	2.0	3.0	3.7	2.4	3.4		
9	--	--	--	--	1.8	3.4	2.3	3.6	4.3	6.7		
10	--	--	2.0	2.0	2.0	2.5	1.1	3.7	2.6	4.8		
Av. AREA	1.6	1.5	2.1	1.8	1.5	2.5	2.5	3.6	3.8	5.6		
B - 1	--	--	2.0	2.5	1.2	2.1	2.9	2.9	2.9	3.7		
2	--	--	1.9	2.0	2.0	2.2	2.4	2.9	3.2	3.4		
3	--	--	3.1	2.2	1.5	2.0	2.4	3.3	3.8	4.7		
4	--	--	1.4	1.5	0.3	2.4	0.9	3.1	3.3	4.1		
5	1.3	1.1	0.9	1.4	1.5	2.1	1.8	2.8	2.9	4.8		
6	-0.6	1.6	1.3	1.4	1.4	2.4	1.7	3.9	4.4	6.0		
10	--	--	0.7	1.4	1.5	3.0	2.2	4.0	2.3	5.2		
11	--	--	2.0	1.4	2.2	2.3	3.1	3.0	1.8	3.3		
12	--	--	--	--	--	--	--	--	--	--		
13	--	--	--	--	--	--	--	--	--	--		
14	--	--	--	--	--	--	1.0	3.2	--	--		
Av. AREA	0.4	1.4	1.4	1.6	1.5	2.2	2.3	3.2	3.1	4.5		
D - 1	--	--	2.1	2.5	2.6	3.0	2.8	4.2	5.1	6.2		
2	--	--	2.0	2.4	3.0	3.4	4.4	4.9	6.2	7.1		
3	--	--	2.7	2.1	3.4	3.3	4.3	4.3	5.7	5.6		
4	--	--	2.4	2.1	2.0	2.3	3.3	4.6	4.6	6.3		
5	--	--	2.4	2.9	3.3	3.3	3.0	3.8	4.5	6.0		
7	--	--	1.6	3.0	2.6	3.9	3.9	5.6	4.6	7.5		
8	--	--	1.8	2.3	2.6	3.6	4.0	4.4	3.8	4.8		
10	--	--	1.2	2.2	2.7	2.6	3.2	4.8	3.4	7.1		
11	--	--	--	--	2.8	4.2	3.8	6.0	--	--		
12	--	--	1.4	2.3	1.4	3.3	4.6	4.4	--	--		
13	--	--	3.1	3.0	2.3	3.9	3.6	5.3	5.9	6.7		
14	--	--	0.4	3.5	2.0	3.3	4.4	3.8	--	--		
15	--	--	1.8	3.1	2.2	2.5	3.1	5.5	--	--		
Av. AREA	--	--	2.1	2.6	2.6	3.4	3.6	4.6	5.0	6.3		
S - 1	--	--	3.3	2.6	3.4	3.5	1.5	4.3	4.3	5.6		
2	--	--	1.4	2.2	2.4	4.2	4.4	7.1	3.4	10.4		
3	--	--	--	--	3.7	3.0	4.1	3.6	4.8	6.7		
5	--	--	--	--	--	--	3.2	3.8	4.2	5.6		
6	--	--	2.6	2.9	2.1	3.9	3.8	5.6	5.1	7.8		
7	--	--	2.6	2.8	3.0	3.3	4.4	5.0	--	--		
8	--	--	1.6	2.4	3.1	3.9	3.5	4.8	4.3	7.5		
Av. AREA	--	--	2.4	2.6	2.9	3.6	3.5	4.6	4.4	7.1		

TABLE 2e.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: e. Tinged and Yellow Stained

LOCATION	GRADES											
	44		54		64		74		45		55	
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA
A - 1	--	--	2.6	2.8	0.6	3.7	1.6	4.5				
2	0.7	1.5	3.3	2.4	2.5	3.7	2.7	4.3				
3	--	--	--	--	--	--	--	--				
4	--	--	--	--	--	--	--	--				
5	--	--	4.0	2.4	2.5	2.4	2.4	4.8				
8	1.2	1.9	--	--	--	--	--	--				
9	--	--	--	--	--	--	--	--				
10	--	--	1.0	4.8	--	--	--	--				
AV. AREA	0.8	1.6	3.0	2.7	2.3	3.4	2.6	4.4				
B - 1	--	--	--	--	3.3	2.7	2.6	4.7				
2	--	--	1.6	1.6	--	--	3.8	2.8				
3	--	--	3.0	3.6	4.5	3.6	2.4	5.1				
4	--	--	--	--	--	--	--	--				
5	--	--	0.4	2.5	1.9	3.1	2.8	4.6				
6	--	--	0.5	1.8	2.1	3.5	2.7	4.7				
10	--	--	1.7	2.8	3.2	3.7	1.5	5.2			2.8	4.5
11	--	--	1.0	1.2	1.7	3.3	1.4	5.2			1.8	4.3
12	--	--	--	--	--	--	--	--			--	--
13	--	--	--	--	--	--	--	--			--	--
14	--	--	--	--	--	--	--	--			--	--
AV. AREA	--	--	1.3	2.4	2.6	3.3	2.3	4.9			2.3	4.4
D - 1	3.0	2.4	1.9	3.1	3.6	4.6	4.2	5.7			1.0	3.6
2	--	--	2.1	3.9	3.2	4.7	5.6	6.6			3.2	4.8
3	3.8	1.7	--	--	4.8	6.5	2.8	5.7			--	--
4	1.6	2.3	--	--	1.0	3.9	--	--			--	--
5	--	--	--	--	3.2	5.9	4.4	5.7			--	--
7	1.2	3.0	2.5	3.7	2.5	4.9	3.0	7.0	2.6	3.9	0.4	3.2
8	3.2	2.6	1.2	1.9	1.7	4.0	4.8	9.8	--	--	--	--
10	--	--	3.2	4.2	3.8	6.6	--	--	--	--	--	--
11	--	--	--	--	--	--	--	--	--	--	--	--
12	--	--	3.0	2.6	3.9	4.4	-2.6	3.9	--	--	--	--
13	--	--	--	--	3.1	4.8	5.0	6.8	--	--	--	--
14	--	--	--	--	--	--	--	--	--	--	--	--
15	2.0	3.3	2.1	3.5	1.6	5.2	2.2	8.3	0.8	3.1	0.9	4.6
AV. AREA	2.4	2.7	2.1	3.3	3.0	4.9	3.7	6.6	1.7	3.5	1.1	4.0
S - 1	--	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	2.3	6.6	3.2	20.4	--	--	--	--
3	--	--	--	--	--	--	--	--	--	--	--	--
5	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	2.7	4.1	2.1	6.7	--	--	--	--	2.8	5.0
7	--	--	3.6	4.2	--	--	--	--	--	--	--	--
8	--	--	1.7	4.0	2.0	6.2	4.8	6.3	--	--	--	--
AV. AREA	--	--	2.5	4.1	2.1	6.6	4.0	13.4	--	--	2.8	5.0

TABLE 2f.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: f. Light Gray

LOCATION	GRADES 38		48		58		68				
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA			
A - 1	2.4	1.5	1.6	2.0	2.2	3.0	2.7	4.7			
2	--	--	2.2	1.4	2.2	1.7	2.6	2.9			
3	--	--	1.7	1.9	2.2	2.6	2.2	4.0			
4	--	--	1.0	1.6	2.2	2.7	2.9	4.2			
5	--	--	1.9	1.9	2.6	2.7	2.7	4.0			
8	--	--	1.3	1.6	0.9	2.6	2.0	3.7			
9	--	--	1.9	2.3	2.6	3.7	1.4	4.0			
10	--	--	1.8	1.7	2.2	3.2	4.4	5.0			
Av. AREA	2.4	1.5	1.7	1.7	2.1	2.6	2.5	3.9			
B - 1	--	--	2.2	1.7	2.6	2.2	4.1	2.8			
2	--	--	2.1	1.4	2.6	2.8	3.0	2.3			
3	--	--	2.6	2.2	1.9	2.4	2.2	3.6			
4	--	--	1.4	1.4	1.7	2.3	0	3.6			
5	--	--	2.1	1.5	2.5	2.2	3.8	3.8			
6	--	--	0.2	1.4	1.8	2.2	4.2	3.8			
10	--	--	1.0	1.4	2.9	2.6	2.2	4.5			
11	--	--	1.6	1.6	2.7	2.0	3.8	3.3			
12	--	--	0.6	2.0	1.9	2.6	--	--			
13	--	--	1.1	1.9	2.2	2.5	--	--			
14	--	--	0	1.4	0	2.8	2.2	3.2			
Av. AREA	--	--	1.7	1.7	2.4	2.3	3.3	3.3			
D - 1	2.8	1.6	2.6	2.6	3.8	2.9	4.8	4.9			
2	--	--	--	--	3.7	3.2	--	--			
3	3.4	2.0	2.7	2.1	3.9	2.9	5.0	4.5			
4	3.2	2.0	2.0	1.9	3.9	2.4	4.2	3.5			
5	2.8	1.8	4.0	2.7	4.5	4.0	--	--			
7	--	--	1.7	1.7	1.0	2.2	4.0	4.1			
8	--	--	2.2	2.0	2.2	3.0	4.8	5.0			
10	1.0	2.0	2.8	2.0	3.6	2.8	2.5	3.4			
11	--	--	2.8	3.0	--	--	--	--			
12	--	--	1.7	2.5	1.2	2.4	--	--			
13	--	--	--	--	--	--	--	--			
14	2.0	1.7	2.2	2.4	1.6	3.0	3.7	3.8			
15	--	--	2.2	2.8	2.4	2.3	--	--			
Av. AREA	2.6	1.9	2.3	2.4	2.7	2.9	4.1	4.1			
S - 1	--	--	3.3	2.9	3.0	3.3	5.6	4.8			
2	1.2	2.0	2.3	2.3	3.3	3.6	--	--			
3	--	--	--	--	--	--	--	--			
5	--	--	2.6	2.4	2.8	3.4	3.2	3.5			
6	2.6	3.1	2.2	2.8	3.0	3.7	2.2	4.2			
7	--	--	3.5	3.0	4.8	3.3	7.2	5.1			
8	4.4	2.1	2.3	2.8	2.6	4.4	--	--			
Av. AREA	2.4	2.3	2.8	2.7	3.3	3.5	4.2	4.3			

TABLE 2g.--AVERAGE COLOR IMPROVEMENT (ΔR_d) AND PERCENT SHIRLEY ANALYZER NONLINT (%S.A.) for each classing office, by areas, for all grades classed in the 1961-62 Color-Trash Survey: g. Gray

LOCATION	36		46		56		66				
	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA	ΔR_d	%SA			
A - 1			1.3	1.7	1.6	3.3	2.7	5.4			
2			1.2	1.3	2.2	1.7	3.2	2.3			
3			1.3	1.9	2.3	2.7	2.1	3.8			
4			1.4	2.1	2.2	3.0	4.0	4.0			
5			1.2	1.8	2.0	3.2	1.6	2.4			
8			1.2	1.9	0.5	2.5	1.8	4.5			
9			4.0	2.8	2.4	3.7	3.0	7.0			
10			2.2	2.9	3.8	4.8	2.0	1.6			
AV. AREA			1.4	1.9	1.9	2.7	2.3	3.7			
B - 1			0.4	1.8	1.8	2.6	1.6	3.2			
2			2.5	1.5	2.3	2.4	3.1	2.3			
3			3.6	2.4	1.8	2.3	1.4	3.3			
4			--	--	2.4	2.9	2.0	4.6			
5			1.0	1.4	2.5	2.2	3.8	3.1			
6			-2.2	1.7	1.2	2.4	1.9	3.6			
10			--	--	4.0	3.5	1.1	4.1			
11			2.2	1.4	3.3	2.7	4.1	3.4			
12			4.0	2.2	1.7	3.5	--	--			
13			--	--	--	--	--	--			
14			2.2	3.2	2.6	2.2	0	3.1			
AV. AREA			1.8	1.7	2.3	2.5	2.6	3.3			
D - 1			--	--	3.7	3.5	1.6	3.0			
2			--	--	--	--	--	--			
3			--	--	4.7	3.7	4.6	5.2			
4	4.6	2.3	2.7	1.7	2.4	2.8	3.7	4.5			
5	--	--	0.6	2.1	0.8	2.6	0.4	4.3			
7	--	--	0.2	2.7	3.2	4.1	3.2	5.0			
8	--	--	2.4	1.8	3.4	3.1	3.4	4.1			
10	--	--	1.6	2.4	4.6	3.3	1.1	4.1			
11	--	--	--	--	--	--	--	--			
12	--	--	2.8	1.8	2.9	3.0	--	--			
13	--	--	--	--	--	--	--	--			
14	3.0	2.2	2.4	2.3	1.6	3.3	2.6	4.0			
15	--	--	--	--	3.0	3.8	--	--			
AV. AREA	3.8	2.2	2.0	2.1	3.2	3.3	2.4	4.3			
S - 1	--	--	2.6	2.9	4.8	4.0	4.2	5.4			
2	--	--	--	--	--	--	--	--			
3	--	--	--	--	--	--	--	--			
5	--	--	--	--	--	--	3.7	4.4			
6	1.3	3.0	2.2	2.0	2.3	4.8	4.0	6.4			
7	--	--	3.6	2.8	2.5	3.8	6.7	5.2			
8	--	--	--	--	1.0	3.2	--	--			
AV. AREA	1.3	3.0	3.3	2.9	3.0	4.0	4.5	5.2			

Cotton, AMS, USDA - September 1963
Prepared for office use,
Standardization Section,
Standards and Testing Branch,
by Josephine J. Tomaszewski

GRADE SURVEYS OF 1962 CROP
AMERICAN UPLAND AND AMERICAN EGYPTIAN COTTONS

Analysis and Summary for Color and Trash

Contents

During the 1962-63 season CN Instruction 910-6 was followed in collecting biweekly samples of every grade of upland and American Egyptian cottons classed. There were two types of grade surveys, one was measurement of color and trash in the laboratory, with measurements of trash made on the Outlook Cotton Trashmeter in Washington; the other was a survey of grade boxes prepared in each of the regular classing offices with three offices also collecting samples of American Egyptian cottons.

1. Laboratory Survey of Upland Cottons

The samples were measured at College Station and Clemson following the procedure established the previous season of sending samples from the Southeast and South Central Areas to Clemson, and those from the Southwest and West to College Station, where color measurements and Shirley Analyzer tests were made. The resulting data sheets were sent to Washington for analysis. Summary color charts and tables of trash measurements were kept current for each office by grade, and by area. These results are filed with those of previous years in the color laboratory.

Figure 1 indicates the average color of cotton classed in White, Light Spotted, Spotted, Tinged, and Yellow Stained grades for all four areas.

Figure 2 shows the range of color classed in White, Spotted, Tinged, and Yellow Stained grades for the four areas.

Figure 3 shows the average of nonlint in 1962 for the United States and for four areas, against the 1953 standards. The data indicate a reduced level of trash in relation to color that has been evident in the past several crop years.

Table 1 contains data for average color change and percent Shirley Analyzer nonlint on 4,518 samples; and trashmeter measurements on 3,840 samples for the four areas in the United States. Measurements of trash were made on the second model Outlook Cotton Trashmeter, which measures the trash on the surface of the sample much as it would appear to the classer. ("Area" figures indicate the fraction of the total area of a sample surface covered by the dark areas of trash, and "Count" figures provide an indication of the relative number of particles the scanning spot crosses and counts.)

The trash results are shown in figure 4 for the laboratory and classification surveys for the White grades.

2. Classification Survey of Upland Cottons

There were 3,324 samples in the grade survey boxes put up by the regular classing offices. These were sent to Washington for color measurement and classification review. The average color of these cottons, as put up to represent each grade of White, Spotted, and Tinged cottons, is shown in figure 5. (Light Spotted cottons were not included in this year's survey.)

3. Grade Survey of American Egyptian Cottons

Samples for both laboratory and classification surveys of American Egyptian cottons were collected in the same manner as for the previous season. Figure 6 shows the average color for American Egyptian grades classed in El Paso, Phoenix, and Pecos, for both surveys. The samples in the classification survey were not held as long in storage as last season and therefore measure this year about the same in yellowness as the laboratory survey.

Figure 7 shows the color range by grades, as classed in each office. Table 2 contains the average Shirley Analyzer nonlint content for the three offices and as combined for the United States total.

Figure 8 shows average Shirley Analyzer nonlint for grades of American Egyptian cottons classed in El Paso, Phoenix, and Pecos in comparison to the level of nonlint shown by a curve representing the grade standards. The results, while generally similar to those of the 1961 season, have slightly less trash content in all grades.

Figure 9 indicates the narrow range of color after cleaning on the Shirley Analyzer. With the exception of one sample from El Paso the color after cleaning is equal to grade 4 and above. Table 3 shows the improvement in color after cleaning on the Shirley Analyzer. This is in terms of increase in reflectance, R_d.

4. Comparisons with Earlier Crops

For comparison with similar data for 1951-1958 crops, see summary charts contained in COTTON GRADE STUDIES, Report No. 2, Color Surveys, by Nickerson and Tomaszewski, May 1959; and Report No. 3, Trash and Color, by Nickerson, Tomaszewski, and Newton, May 1959, prepared for use at 1959 Universal Grade Standards Conference. For the 1961 crop, see Grade Survey office report, by Tomaszewski, July 1962. For diagrams of data for separate offices and areas, from 1951 to date, consult files in Standardization Section.

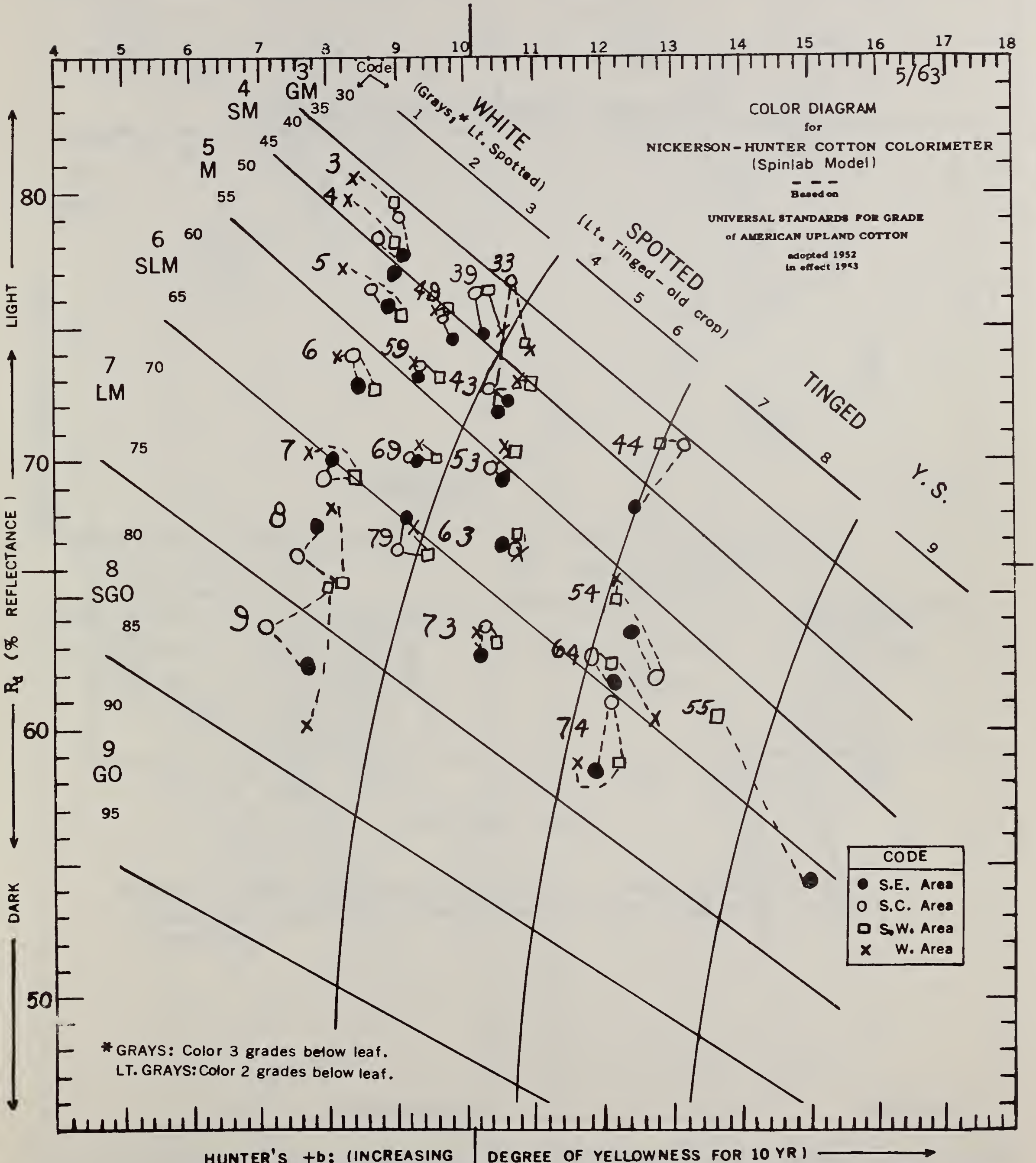


FIGURE 1.--1962-63 COLOR-TRASH SURVEY: Average color of cotton classed in White, Light Spotted, Spotted, Tinged, and Yellow Stained grades for four areas.

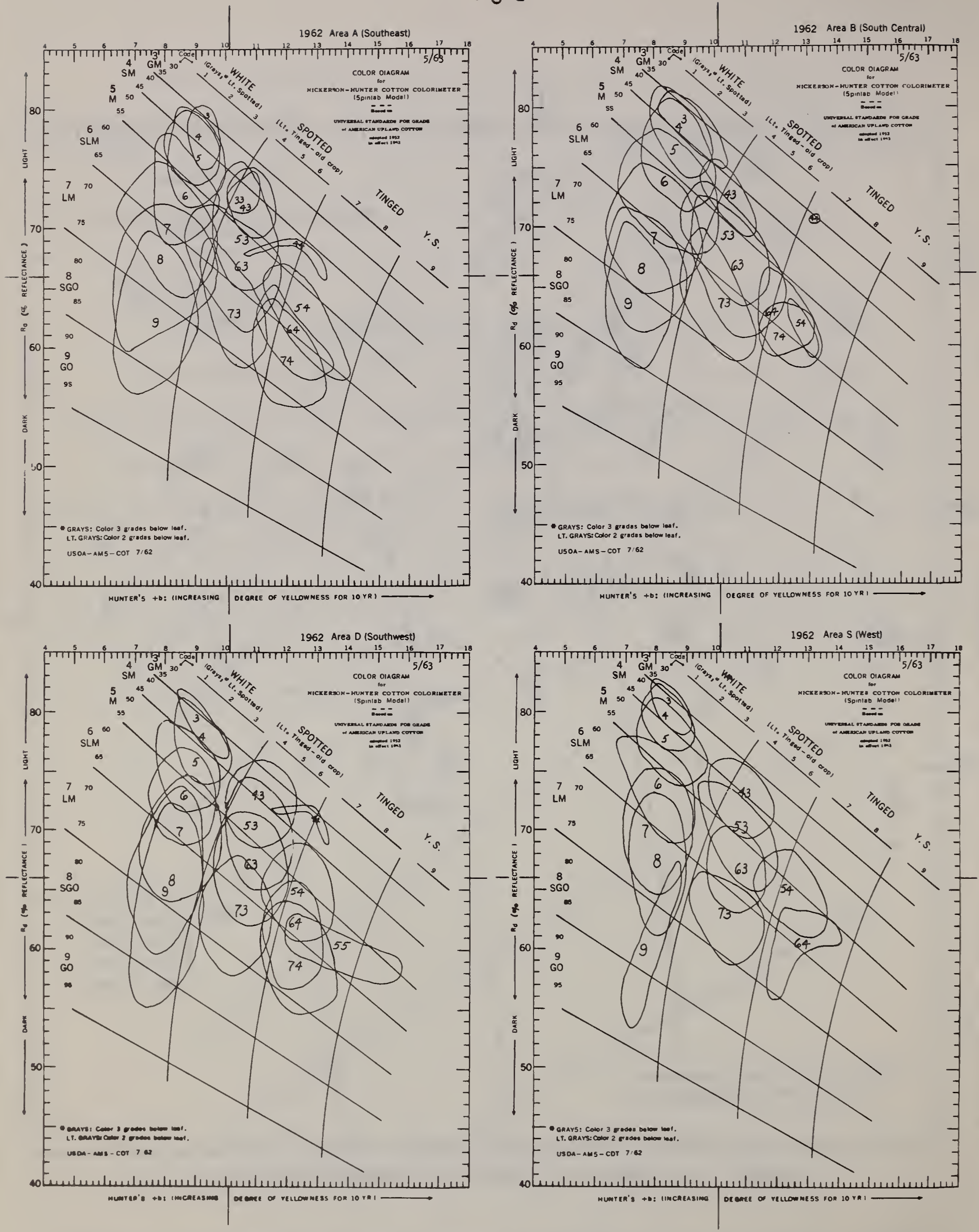


FIGURE 2.--1962 COLOR-TRASH SURVEY Range of color in White, Spotted, Tinged, and Yellow Stained grades for four areas.

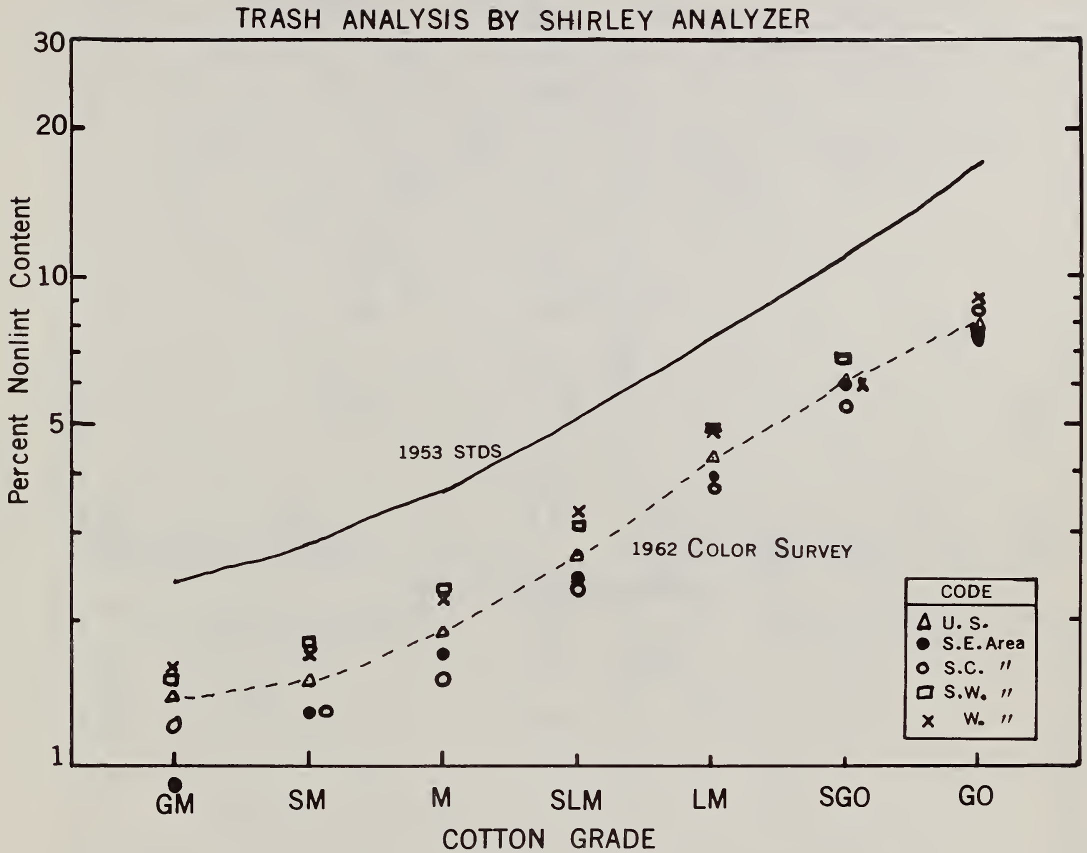


FIGURE 3.--1962-63 COLOR-TRASH SURVEY: Average of nonlint for the United States and four areas shown against a curve of the 1953 standards.

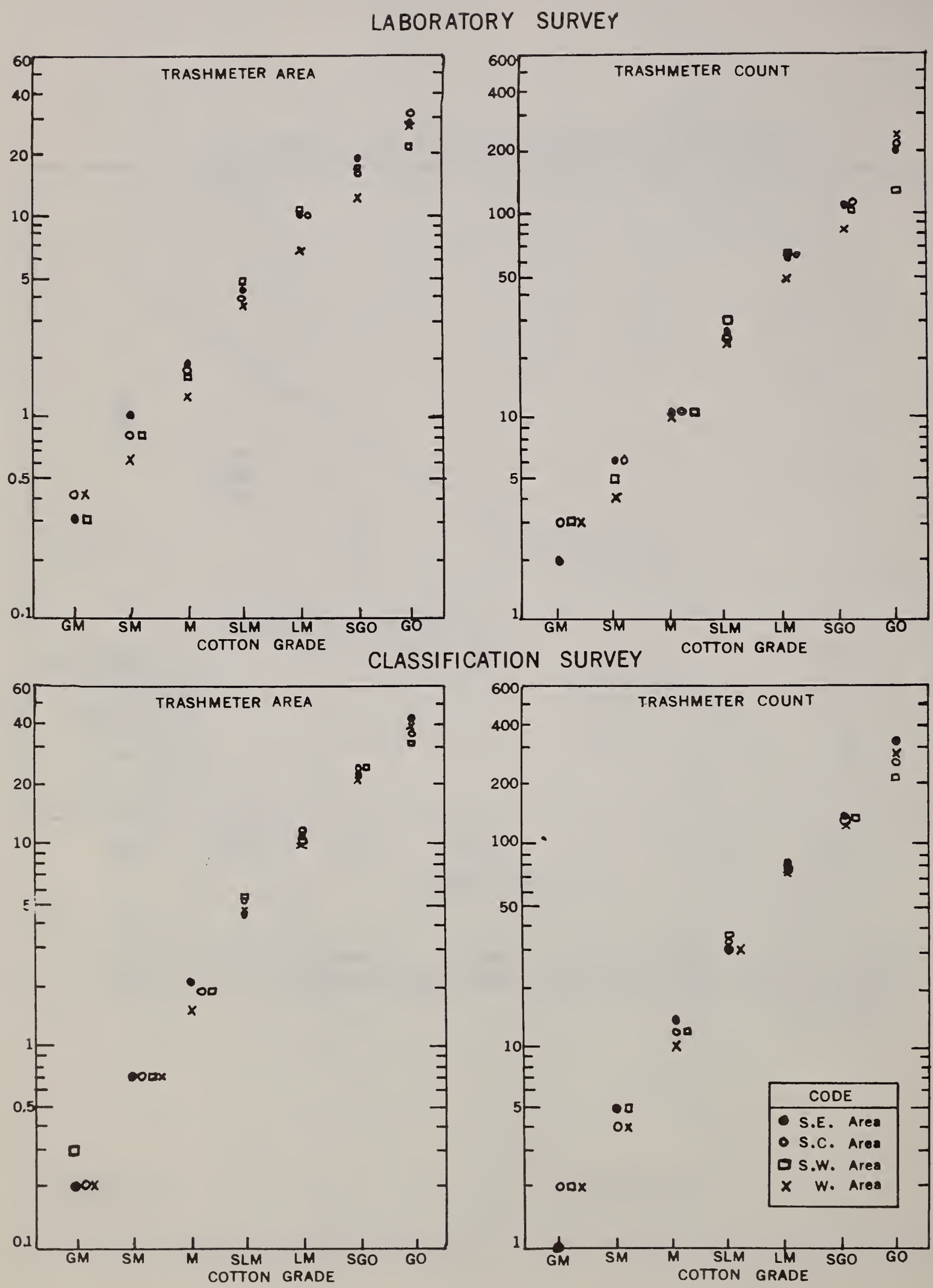


FIGURE 4.--Average of trashmeter measurements in the 1962-63 Color-Trash Survey (laboratory) and the Grade Survey Boxes (classification) for white grades in the four areas.

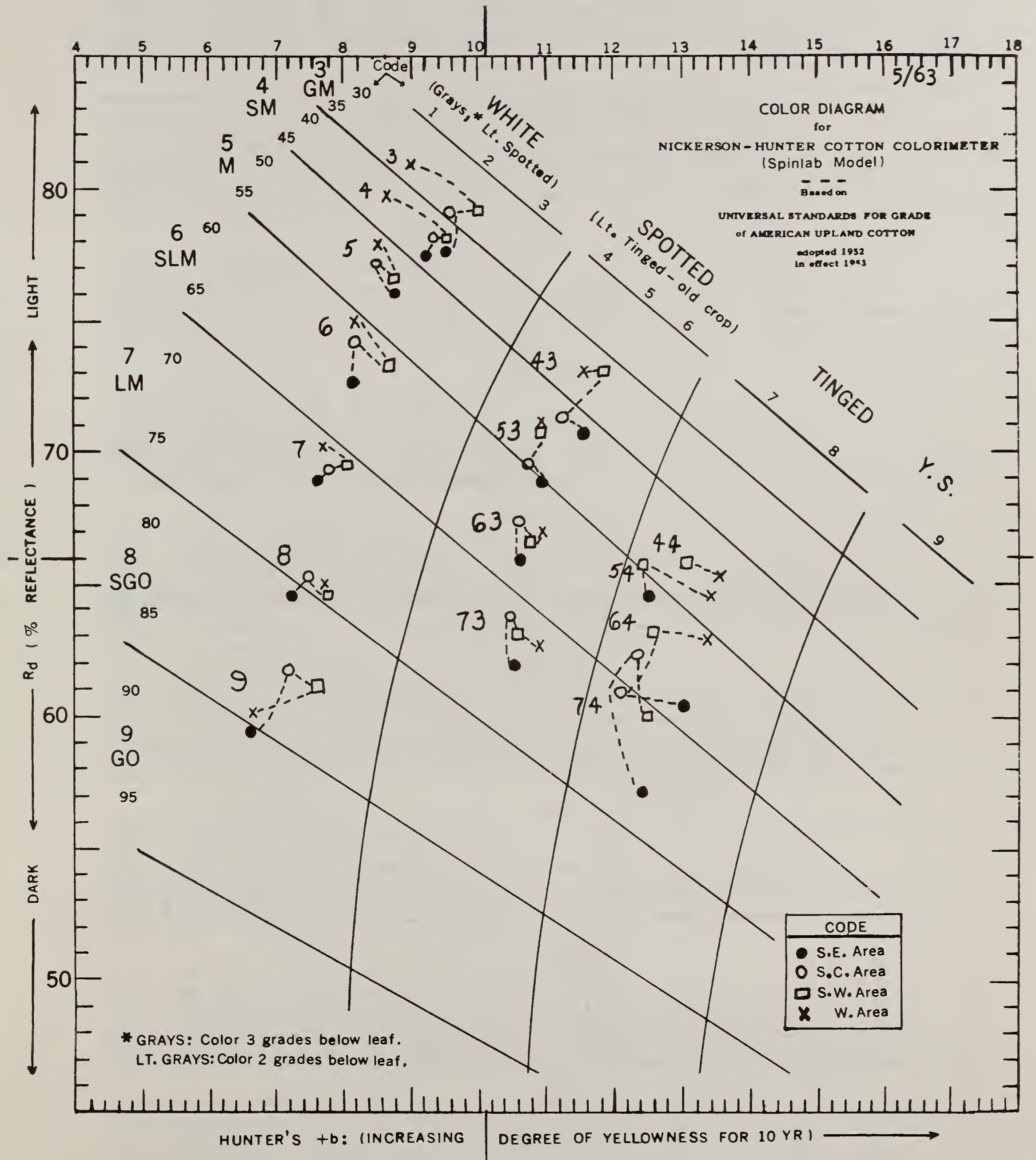


FIGURE 5.--1962-63 GRADE SURVEY BOXES: Average color of typical samples of cotton classed in White, Spotted, and Tinged grades.

TABLE 1.--AVERAGE COLOR IMPROVEMENT (ΔR_d), PERCENT SHIRLEY ANALYZER NON-LINT (% S.A.) AND TRASHMETER MEASUREMENTS OF AREA AND COUNT for four areas in the United States for all grades classed in the 1962-63 Color-Trash Survey. 1/

AREAS	GRADES 3				4				5				6			
	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count
							WHITE									
A	0.2	0.9	0.3	2	0.7	1.3	0.9	6	1.5	1.8	1.9	12	2.2	2.4	4.2	26
B	0.9	1.2	0.4	3	0.7	1.3	0.8	6	1.1	1.6	1.8	11	2.1	2.3	3.9	25
D	1.1	1.4	0.3	3	1.5	1.8	0.8	5	2.2	2.3	1.7	11	3.5	3.0	4.8	30
S	1.4	1.7	0.4	3	1.7	1.7	0.6	4	2.3	2.2	1.4	10	3.9	3.3	3.7	24
Av. U.S.	1.1	1.4	0.4	3	1.2	1.5	0.8	5	1.8	2.0	1.7	11	2.6	2.7	4.2	27
							PLUS GRADES									
A									1.4	1.6	2.1	13	2.2	2.4	3.9	24
B									1.5	1.6	2.4	14	2.6	2.5	5.0	29
D									2.8	2.1	2.2	14	3.6	2.9	3.9	25
S									2.6	2.3	2.0	12	3.8	3.2	3.3	21
Av. U.S.									1.9	1.8	2.2	13	3.0	2.7	4.1	25
							LIGHT SPOTTED									
A	1.8	1.0	0.7	5	1.1	1.5	1.4	10	1.5	2.2	3.2	21	2.7	3.2	6.0	38
B	1.1	1.2	0.5	3	0.9	1.6	1.5	10	1.7	2.0	2.8	19	2.1	2.8	6.2	41
D	1.7	1.7	0.8	4	1.8	2.1	1.1	8	2.3	2.7	2.1	14	3.6	3.8	6.0	35
S	2.1	1.6	2.0	12	1.9	2.2	1.4	9	2.7	2.8	2.6	18	3.9	4.0	6.8	45
Av. U.S.	1.5	1.4	0.8	5	1.4	1.9	1.2	9	2.0	2.4	2.6	17	3.1	3.5	6.2	39
							SPOTTED									
A	1.5	1.2	--	--	1.0	1.9	3.1	20	1.5	2.5	4.2	28	2.3	3.3	10.3	65
B	1.0	1.1	--	--	0.9	1.5	2.4	20	1.4	2.0	5.3	36	2.1	3.2	10.5	67
D	2.4	1.5	0.5	4	2.3	2.4	1.2	8	2.5	3.2	4.6	31	3.8	4.1	7.9	53
S	1.4	2.2	--	--	2.4	2.3	1.9	14	2.6	3.1	5.5	34	4.0	4.5	7.8	53
Av. U.S.	1.9	1.4	0.5	4	1.8	2.2	2.0	14	2.1	2.8	4.8	32	3.0	3.7	9.0	59
							TINGED									
A					1.3	1.8	--	--	1.3	2.0	8.5	66	1.8	3.3	18.4	129
B					1.6	1.2	--	--	1.7	1.6	15.8	112	1.5	2.7	22.5	150
D					1.4	3.2	--	--	2.5	3.5	10.1	68	3.2	4.9	16.0	111
S					--	--	--	--	2.2	3.7	8.1	58	2.6	3.7	25.4	157
Av. U.S.					1.4	2.2	--	--	2.1	3.0	9.7	69	2.5	4.0	18.3	125
							LIGHT GRAY									
A	0	1.1	--	--	1.5	1.5	1.1	10	2.2	2.2	2.8	23	1.8	3.3	10.7	70
B	0.6	1.5	0.6	3	1.8	1.8	1.5	11	1.5	2.0	3.8	26	2.8	3.2	9.6	68
D	2.4	1.6	0.7	5	2.7	2.1	1.4	9	3.4	2.5	3.8	27	4.4	3.5	10.2	69
S	2.8	2.2	1.8	10	3.1	2.1	1.5	10	3.9	2.8	3.2	23	5.7	3.8	7.3	52
Av. U.S.	1.9	1.7	1.0	6	2.3	1.9	1.5	10	2.7	2.4	3.4	24	3.4	3.4	9.7	66
							GRAY									
A	--	--	--	--	1.3	1.8	3.4	20	1.2	2.3	6.0	40	1.5	3.0	12.8	74
B	0	1.3	--	--	1.0	1.4	2.2	16	1.4	1.9	5.8	42	0.9	[illegible]	22.5	167
D	5.4	2.0	1.4	11	2.3	2.2	1.6	11	4.3	2.8	5.4	39	3.5	4.1	23.4	143
S	--	--	--	--	3.5	2.5	2.1	16	3.7	2.9	5.2	36	4.6	3.6	16.6	112
Av. U.S.	2.7	1.6	1.4	11	2.1	2.0	2.2	15	2.7	2.5	5.[illegible]	39	2.4	3.1	18.9	124

1/ 4518 samples on Shirley Analyzer; 3840 on Cotton Trashmeter

Table 1.--Continued

AREAS	7				8				9			
	GRADES											
	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count	ΔR_d	% S.A.	Trashmeter Area	Trashmeter Count
					WHITE							
A	3.2	3.9	9.9	62	4.3	6.0	19.3	120	5.3	7.4	28.9	203
B	3.2	3.7	9.9	63	4.5	5.4	18.2	122	5.7	8.0	30.2	207
D	5.3	4.9	8.7	65	6.4	6.8	18.7	121	7.4	7.3	22.2	145
S	5.4	4.8	6.9	48	6.6	6.0	12.3	88	6.6	9.0	28.8	212
Av. U.S.	4.3	4.3	9.0	61	5.3	6.1	17.9	116	6.0	7.7	27.9	192
					PLUS GRADES							
A	3.5	3.6	9.1	55	4.4	5.3	14.5	90	7.6	9.0	19.6	139
B	2.9	3.6	9.0	58	4.3	5.3	15.5	101	6.0	7.6	22.7	161
D	5.2	4.3	9.6	59	7.2	6.3	16.0	101	7.9	8.3	21.8	136
S	6.0	4.3	6.0	38	7.1	6.6	12.9	87	3.2	6.6	22.5	155
Av. U.S.	4.1	3.9	8.9	55	5.4	5.7	15.2	97	7.1	8.3	21.4	145
					LIGHT SPOTTED							
A	2.9	4.6	14.8	89								
B	3.1	4.1	13.4	89								
D	5.1	5.3	12.0	79								
S	5.2	5.5	11.3	76								
Av. U.S.	4.2	4.9	12.8	83								
					SPOTTED							
A	3.4	5.1	22.7	148								
B	2.5	4.1	19.8	123								
D	4.5	5.7	16.8	107								
S	5.0	6.8	18.1	126								
Av. U.S.	3.8	5.3	19.1	124								
	TINGED								Y. STAINED (MID)			
A	2.1	5.6	47.2	315					4.1	3.6	--	--
B	2.1	5.7	24.8	188						--	--	--
D	3.9	6.2	30.4	206					2.5	4.1	15.2	120
S	4.2	7.5	28.8	220					--	--	--	--
Av. U.S.	3.2	6.0	31.3	218					3.0	4.0	15.2	120
	BELOW GRAY											
A	--	--	--	--								
B	-2.4	3.3	--	--								
D	--	--	--	--								
S	--	--	--	--								
Av. U.S.	-2.4	3.3	--	--								

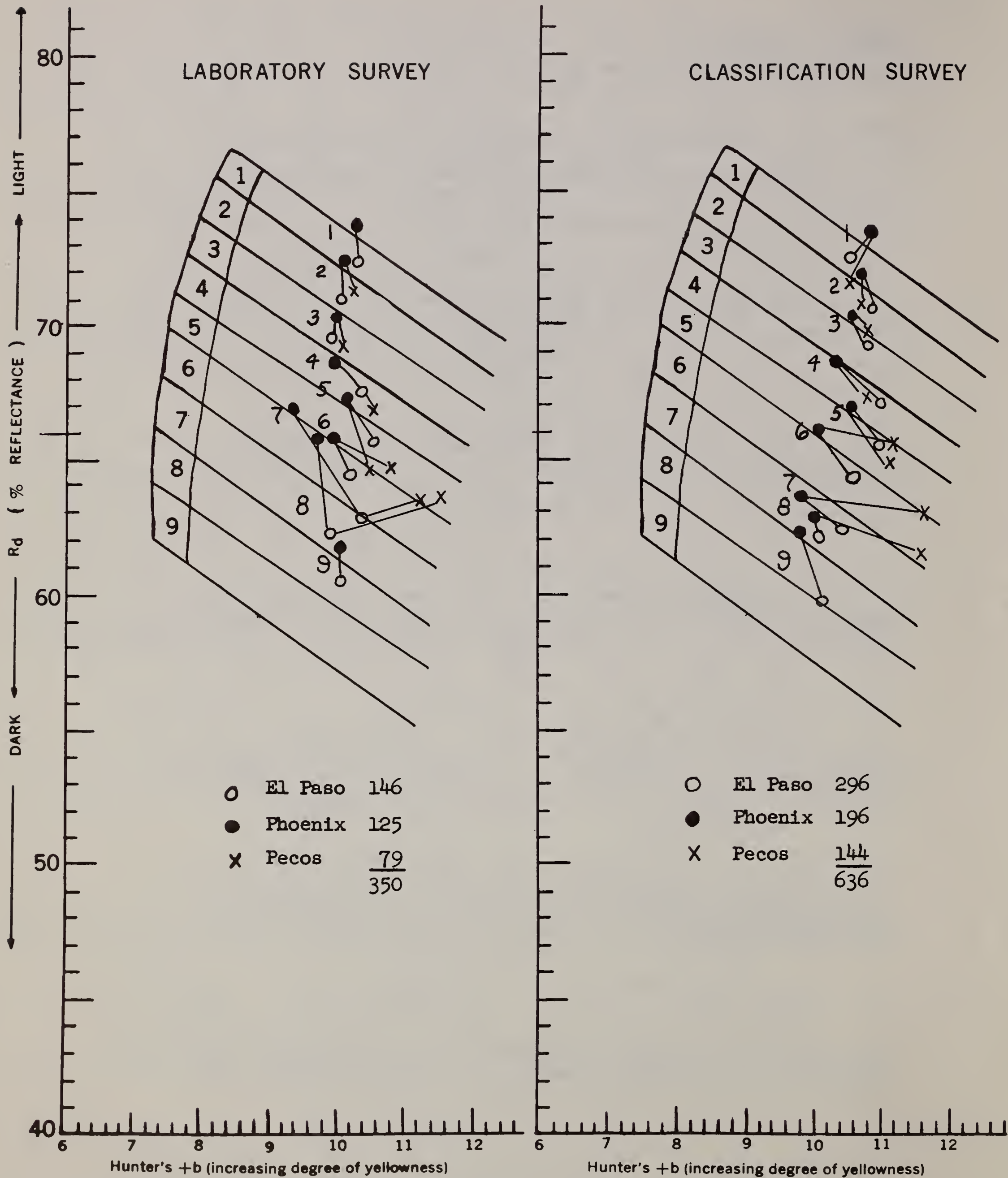


FIGURE 6.--1962 AMERICAN EGYPTIAN SURVEY: Average color of American Egyptian grades classed in El Paso, Phoenix, and Pecos, for laboratory and classification surveys.

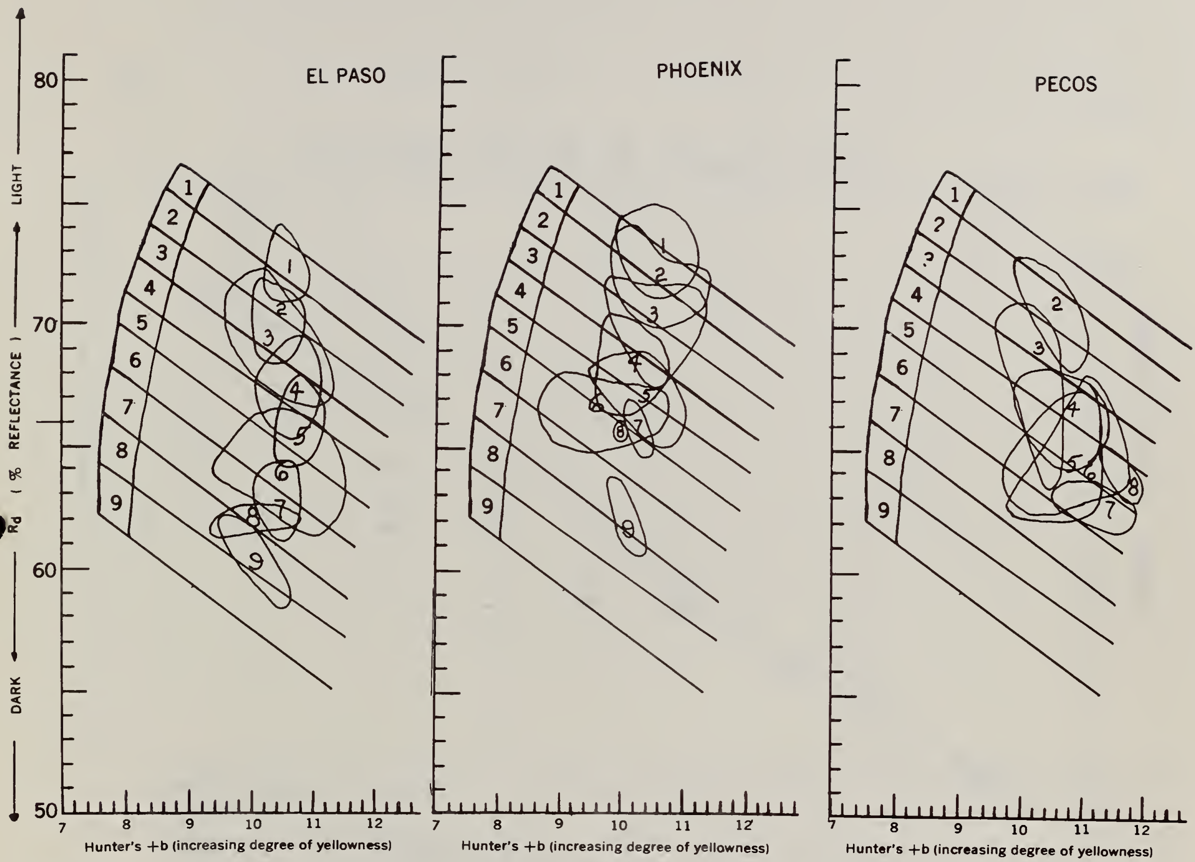


FIGURE 7.--1962-63 AMERICAN EGYPTIAN SURVEY: Range of color of American Egyptian cottons classed in El Paso, Phoenix, and Pecos, by grades.

TABLE 2.--PERCENT TRASH BY THE SHIRLEY ANALYZER FOR THE 1962-63 AMERICAN EGYPTIAN COLOR-TRASH SURVEY

Place	Grade								
	1	2	3	4	5	6	7	8	9
El Paso	1.8	2.7	3.0	4.1	5.2	6.4	5.9	10.2	9.4
Phoenix	1.9	2.4	3.1	4.0	4.2	4.0	6.6	7.8	6.0
Pecos	-	2.2	3.1	4.7	4.7	6.2	8.2	10.1	-
U. S.	1.9	2.5	3.1	4.2	4.6	5.7	6.7	9.8	8.0

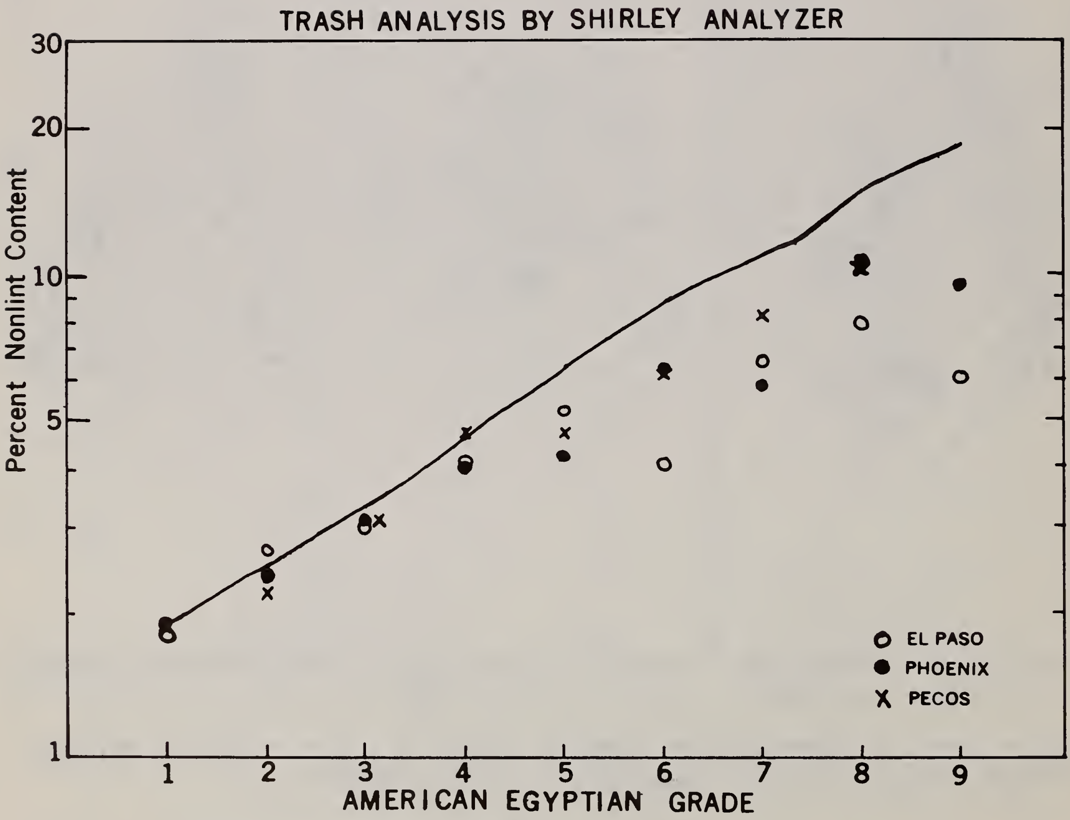


FIGURE 8.--1962-63 AMERICAN EGYPTIAN SURVEY: Average of nonlint of American Egyptian cottons from El Paso, Phoenix, and Pecos shown in relation to the curve for nonlint in the standards.

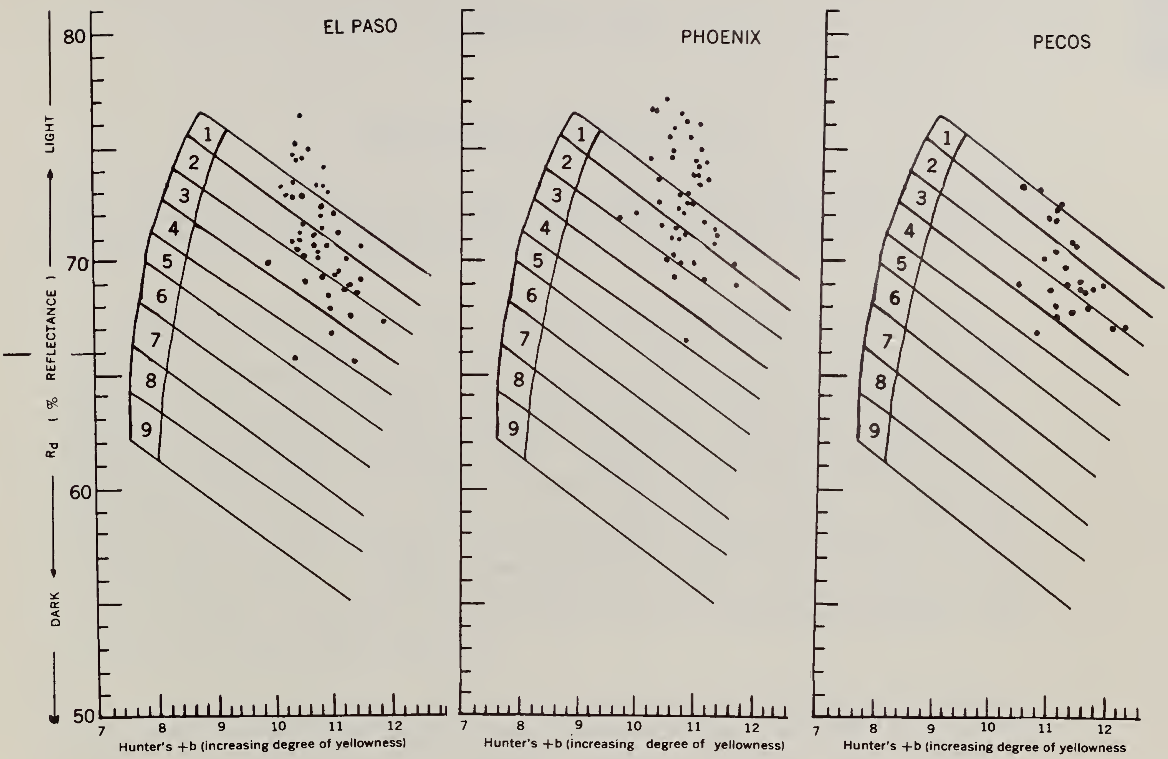


FIGURE 9.--1962 AMERICAN EGYPTIAN SURVEY: Range of cleaned lint of color (after cleaning on the Shirley Analyzer) of American Egyptian cottons from El Paso, Phoenix, and Pecos.

TABLE 3.--COLOR CHANGE (in terms of increase in Reflectance, ΔR_d) FOR S.A. SAMPLES AFTER CLEANING, COMPARED TO ORIGINAL R_d.

Place	Grades								
	1	2	3	4	5	6	7	8	9
El Paso	2.6	3.0	2.8	3.7	3.5	6.1	5.4	7.2	7.5
Phoenix	3.0	2.7	3.3	3.8	4.4	4.4	4.7	4.4	6.4
Pecos	-	2.1	3.1	3.3	5.1	3.6	5.2	4.7	-
U. S.	2.8	2.8	3.1	3.7	4.3	5.0	5.2	5.9	7.0

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

EFFECTS OF STORAGE ON COTTON QUALITY:
Fiber, Spinning, and Finishing Tests on 38 Cottons Before and After Storage Under Controlled Conditions*

Background, and General Plan

Studies of cottons held in storage have established the pattern of color change that takes place with time, temperature, and humidity, but studies are more fragmentary regarding changes in other fiber, yarn, or fabric factors that are caused by storage of raw cotton.

A literature survey in 1951 (1) indicated that results of studies of fiber and yarn strength of stored cottons seemed conflicting, sometimes positive, sometimes negative. For example, cottons found in an Arizona pueblo ruin, at least 500-600 years old, had a tensile strength only slightly below what would be considered average today (2). Hawkins and Thomas in Arizona (3) concluded that cottons containing high moisture content produced yarns of lower strength index than those with low moisture content. Reports from India showed increases as well as decreases in yarn strength with storage, the increases seeming to come at the end of the rainy season. In 1914 Ahmad and Gulati (4) reported that cottons held in desiccators at relative humidities below 90 percent did not lead to deterioration in fiber strength, but that at saturated humidity deterioration was rapid and complete.

On a series of cottons stored in the laboratory for 17 years, Nickerson (1) reported considerable yellowing in high grades compared to low grades, a small but consistent loss of fiber strength related to grade change caused by exposure in the field, but no significant fiber strength loss in storage. The original study in these samples was reported in 1933 (5), and on duplicate samples of three Texas cottons that were included in these tests, Grimes (6) in 1936 reported fiber strength losses after 1 year of storage of 7 to 18 percent, and after 2 years a loss of 25 to 33 percent. No such magnitude of change--in fact, no significant change--was found by Nickerson in the corresponding samples stored in Washington.

---

* Based on April 1961 office report prepared by Dorothy Nickerson and Josephine J. Tomaszewski, Standardization Section, Standards and Testing Branch, Cotton Division.

Looking over the results of these several studies again, it begins to appear that the pattern of change in strength may be as much dependent on the conditions of storage as are the changes in color.

Only a few of the earlier storage studies include spinning tests, and for these usually only strength results were reported. In order to obtain full fiber, spinning, and finishing test data on samples of similar cottons after storage under several conditions of temperature, humidity, and time, samples from 28 bales of American Upland, and 10 bales of American Egyptian cottons were obtained in 1958 for testing before and after storage.

Three conditions were selected for storage. These were based on previous tests which indicated that changes under storage at 50° F./50% R.H. might be small, while those under 100° F., might be large, with more change under high than under moderate humidities. Under these three conditions samples of the same cottons were stored 1 year at 100° F., high humidity (85-90% R.H.), and 2 years at 50° F., 50% R.H., and 100° F., 50% R.H. Test results on these 38 cottons are reported and summarized.

Procedure

Enough cotton to make four 5-pound spinning test lots was obtained from each of 38 bales. Of these, 28 were selected to cover the range of grades in American Upland cottons, and 10 to cover the range of grades in American Egyptian cottons. The American Upland cottons were assembled (March 1958) into four sets. One set was shipped to the Cotton Division's spinning laboratories for immediate fiber, spinning, and finishing tests, the other sets were baled and shipped, one set to Beltsville, Maryland for storage at 50° F., 50% R.H., two sets to Experiment, Georgia, one for storage at 100° F., 50% R.H., the other at 100° F., high humidity. The bales were put into storage about April 1.

Within a given storage period, more color change occurs in high than in low grades, and since a similar pattern of change might be expected to apply in the case of other quality factors, the cottons selected for study included more high than low grades. When several bales of the same grade were included, each was selected to represent cotton from a different area. The test included four bales each of the grades, GM, SM, M, one of SLM, three each of LM and GO, two each of SM Sp., M Sp., SLM Sp., and one each of LM Sp., SM Tg., SLM Tg.

About 6 months after the Upland cottons were selected, four spinning test lots from each of 10 bales of American Egyptian cottons, were added to the study, two each of grades 1, 3, 5, 7, and 9. One set of these samples was sent to the spinning laboratories for immediate testing, the three other sets were assembled into small bales and put into storage under the conditions used for the American Upland cottons, with the single exception that for the October 1958-April 1959 period the samples under storage at 50° F., 50% R.H. were held in a basement storage vault belonging to the Cotton Division instead of being sent to Beltsville for storage.

In the spring of 1959, after approximately 1 year in storage for the American Upland cottons and 6 months for the American Egyptian cottons, all cottons were returned to the Washington laboratory where they were classed and measured for color. The amount of change was about as expected. Cottons held at 50° F./50% R.H. showed little or no color change. Of the cottons held at 100° F./ high humidity, the White grades from GM through LM changed to fully Spotted grades, most of the Spotted grades changed to Tinged, and the Tinged grades changed either to a very deep Tinge, or were called "Below Grade." Cottons held 2 years at 100° F./50% R.H. showed about half as much color change in the lower grades, and fully as much change in the higher grades as those held only half as long a time at the same temperature but under higher humidity.

The color change in 6 months to 1 year under high humidity was so considerable that comparisons of before-and-after tests should provide significant results. Because of this, and because it was not convenient to continue maintaining the high humidity conditions of storage at 100° F., the cottons stored under these conditions were shipped to the spinning laboratory for testing. The remaining samples were baled and returned to their same storage conditions for another year.

In April of the next year (1960) they were removed from storage and sent to the Washington laboratories. After classification and color measurements were obtained on each sample, they were shipped to the spinning laboratories for a complete series of fiber, spinning, and finishing tests.

Results

All tests that usually are made in our testing laboratories have been completed on these cottons. The results are summarized in table 1, which is based on details reported for each bale in Appendix A, pages 24-37, for American Upland cottons, and Appendix B, pages 38-43, for American Egyptian cottons. In these tables the level of test before storage is used as a zero base line, and differences in test level after storage are shown against this base as plus or minus differences.

Results are reported separately for white and colored grades of Upland cottons, and for American Egyptian grades. Although in some cases the summary table hides the consistency of test results, and any trends that may show some changes to be greater in high than in low grades, it allows all of the data to be assembled for general comparison. In commenting on these comparisons, the several storage conditions will be referred to as "50/50," "100/50," and "100/H," to represent the temperature and relative humidity of the three conditions used.

From the summary table, with reference to the detailed tables, the following conclusions are drawn regarding test results.

Table 1.--Summary of results before and after storage under controlled temperature and humidity for classification, fiber, yarn and finishing tests on cottons from 38 bales that cover the range of grades in American Upland and American Egyptian cottons

Test identification[3/]	AMERICAN UPLAND COTTON[1/]								AMERICAN-EGYPTIAN COTTON[2/] GRADES			
	White Grades				Spotted and Tinged Grades							
	Average of measurement before storage	Average of differences after storage for			Average of measurement before storage	Average of differences after storage for			Average of measurement before storage	Average of differences after storage for		
		2 years at		1 year at		2 years at		1 year at		18 mos. at		6 mos. at
		50°/50%	100°/50%	100°/85%		50°/50%	100°/50%	100°/85%		50°/50%	100°/50%	100°/85%
Classification:												
Grade....................index	94	0	-2	-3	88	-3	- 9	-15	83	-2	-6	-12
Staple length...........inches	34	-2	-2	-1	31	-1	- 1	- 2	45	-1	-2	- 2
Fiber length:												
Array, Upper Quartile....inches	—				—				1.41	0	-0.01	+0.01
" Mean Length................	—				—				1.17	0	-0.01	0
" Coeff............percent	—				—				29	0	+1	0
Fibrograph, U.H.M........inches	1.04	-0.01	0	-0.01	90	+0.01	0	+ 0.01	1.29	-0.01	-0.01	+ 0.01
" Uniformity....ratio	81	-2	-2	-2	80	-1	- 1	- 2	83	-1	-2	- 6
" Mean Length........	0.85	-0.03	- .03	- .03	.72	- .01	- 0.1	- .02	1.07	- .03	-0.03	-0.07
Fiber fineness and maturity:												
Micronaire...............reading	4.2	0	0	0	4.2	0	+ 0.1	0	3.4	+0.1	+0.1	+ 0.1
Fineness (Causticaire)..ug/inch	4.1	+0.2	+0.3	+0.2	4.6	-0.2	- 0.3	- 0.4	3.2	+0.1	0	0
Maturity (Causticaire)....index	79	-1	-2	-1	75	+2	+ 3	+ 3	75	+2	+2	+ 2
Fiber strength (Pressley):												
Zero gage.........1,000 p.s.i.	82	+1	0	-1	75	0	0	0	97	+5	+1	+ 2
1/8 inch gage.............index	100	+1	-2	+1	87	+3	0	- 1	157	-5	-4	+ 1
Shirley Analyzer:												
Total nonlint content...percent	3.7	+ .2	+ .3	+ .5	6.4	+ .2	+ .2	0	6.8	+0.2	+0.5	+ .2
Color of raw cotton:												
Reflectance.................Rd	72.9	0	-2.0	-3.8	67.9	+0.1	- 2.5	- 7.4	66.4	-1.7	-3.9	- 6.3
Yellowness..................+b	8.2	0	+2.4	+2.7	11.8	-0.2	+ 1.6	+ 1.4	11.1	+0.4	+1.8	+ 1.8
Index........................	95	0	-2.0	-5	87	+1.0	- 3.0	-12	84	-2	-5	-10
Sugar content.............percent	0.3	- .1	- .2	- .3	0.3	+ .1	- .1	- .3	0.4	+0.1	0	- 0.3
Acid alkaline value......pH units	7.1	- .2	- .6	+1.6	6.1	+ .1	- .2	+ 2.4	6.2	-0.1	-0.5	+ 0.3
Manufacturing waste:												
Picker.................percent	1.3	+ .3	+ .4	+ .8	2.4	+ .1	+ .3	+ .2	4.0	+ .2	0	+ 0.4
Card...................percent	7.3	+1.1	+1.1	+1.1	9.1	+ .2	+ .1	+ .7	10.2	+ .1	- .3	- 0.4
Picker and card.........percent	8.5	+1.4	+1.4	+1.8	11.0	+ .6	+ .6	+ .9	13.7	+ .3	- .3	0
Comber.................percent	—				—				12.3	+1.2	+1.1	+ 3.9
Picker, card, and comber...percent	—				—				25.1	+1.2	+ .7	+ 2.5
Neps.......per 100 sq. in. card web	23	-3	-3	-6	19	-8	- 8	-11	8	-1	-1	0
Strength of yarn skeins:												
8s (73.8 tex)..........pounds	—				30.6	-8	-15	-11				
22s (26.8 tex)..........pounds	123	-2	-7	-5	96	-2	- 5	- 5				
50s (11.8 tex)..........pounds	43	0	-1	-1								
50s combed..............pounds	—				—				72	0	-1	- 1
80s combed..............pounds	—				—				41	0	-2	- 1
Appearance of yarns (grey):												
8s (73.8 tex)..........index	—				101	+3	+ 4	+ 6				
22s (26.8 tex)..........index	102	-1	+6	+3	94	+2	+ 4	+ 3				
50s (11.8 tex)..........index	98	-6	-1	-3								
50s combed..............index	—				—				114	+2	+5	+ 5
80s combed..............index	—				—				107	+1	0	+ 2
Color of yarn:												
Grey:												
Reflectance.................Rd	69.1	- .1	-2.8	-3.3	60.6	+ .4	- 3.5	- 6.2	61.9	-1.0	-3.8	- 6.3
Yellowness..................+b	11.3	- .1	+2.4	+2.6	14.7	+ .2	+ 1.8	+ 0.9	15.1	0	+1.4	+ 1.2
Color index..................	96	0	+4.4	+3	91	+ .2	- 1	-12	93	-3	-5	-12
Bleached:												
Reflectance.................Rd	83.5	- .1	+ .6	- .7	80.5	+ .6	+ .3	- 0.1	81.4	+1.0	+1.2	+ 0.4
Yellowness..................+b	3.4	- .2	+ .6	+1.1	4.0	+ .3	+ .9	+ 2.0	4.9	+0.6	+0.1	+ 1.1
Color index..................	100	0	-2	-6	91	0	- 3	- 8	89	0	+3	- 3
Dyed after bleaching:												
Reflectance.................Rd	30.0	-1.1	+0.3	+2.2	27.9	-0.6	+ 1.1	+ 2.3	26.8	+ .5	+1.2	+ 3.5
Blueness....................-b	25.4	+0.7	0	-0.5	24.9	+0.4	- 0.3	- 1.6	25.3	- .2	- .8	- 2.0
Color index..................	100	+5	-1	-7	98	+3	- 6	- 9	101	-2	-6	-15
Luster of 50s combed yarn:												
Grey....................percent	—				—				41	-2	-1	+ 2
Mercerized..............percent	—				—				54	0	0	+ 2

1/ Averages for 28 bales of American Upland cottons covering the range of A.U. grades are from ~~table I~~, Appendix A.

2/ Averages for 10 bales of American-Egyptian cottons covering the range of A.E. grades are from ~~table II~~, Appendix ~~A~~B.

3/ Abbreviations and units are as used in Annual Cotton Quality Survey Reports, e.g. Agr. Information Bull. No.227, April 1960.

4/ 1 sample only.

Grade. Grade changes differed widely, according to conditions of storage. Under 50/50 conditions there was a minimum of change, the white grades changed very little, colored grades and American Egyptian grades showed a small average change. Storage under 100/H for 1 year caused a very considerable average change, even more in American Upland cottons than was caused by 2 years storage at 100/50. Storage of American Egyptian cottons for 6 months at 100/H also produced more grade change than a longer storage period (18 months) at 100/50.

In general, the grade changes in this test follow the pattern of color change demonstrated by other samples in previous storage reports (7, 8, 9). Translated into price differences,1/ there was a 5-point loss for white grades stored at 50/50, 41 points for the colored grades, 147 points for American Egyptian cottons. For storage under 100/50, white grades averaged a loss of 137 points, colored grades 328 points, American Egyptian grades 544 points. For storage under 100/H, even for a shorter time, the loss for the white grades was 231 points, for colored grades we do not have all the data (but estimate it at about 600 points), for American Egyptian grades it was 1,005 points.

Staple. Classer's staple averaged shorter, from 1/32" to 1/16", for all conditions of storage. See figure 1. For the white grades, whether stored under 50/50 or under 100/50, the average change was 1/16", for the colored American Upland and the American Egyptian grades it was 1/32" to 1/16" shorter. Of all 38 samples, 30 were called 1/32" to 1/4" shorter after storage.

Classification before storage was made on Upland and American Egyptian cottons at different times, and the classification after storage was not made immediately after removing samples from storage, but several weeks later when the bales were assembled after shipment to Washington. They would all have had a chance to adjust to the classing room conditions, and, while we cannot explain why these differences occur, it seems probable that, for the samples in this particular study, they are real. These changes do not follow the pattern of change in grade and color, for there is as much change in staple under cool, dry storage as under hot, humid storage. There seems no tendency for changes to be greater or less with high grades than with low grades, as there is in color, but there is a tendency for short cottons to change less than long cottons.

Length and length uniformity, by measurement. Length measurements for the white grades generally support the direction, but not the degree of change found by classification. After 50/50 storage the U.H.M. of 14 out of 19 white bales measured shorter by .01" to .04", but of the shorter length colored bales, only two measured shorter, four measured longer. After 100/50 storage six white grades measured longer, eight

---

1/ Based on 1960 loan premiums and discounts: 1" for American Upland; 1-7/16" for American Egyptian cottons.

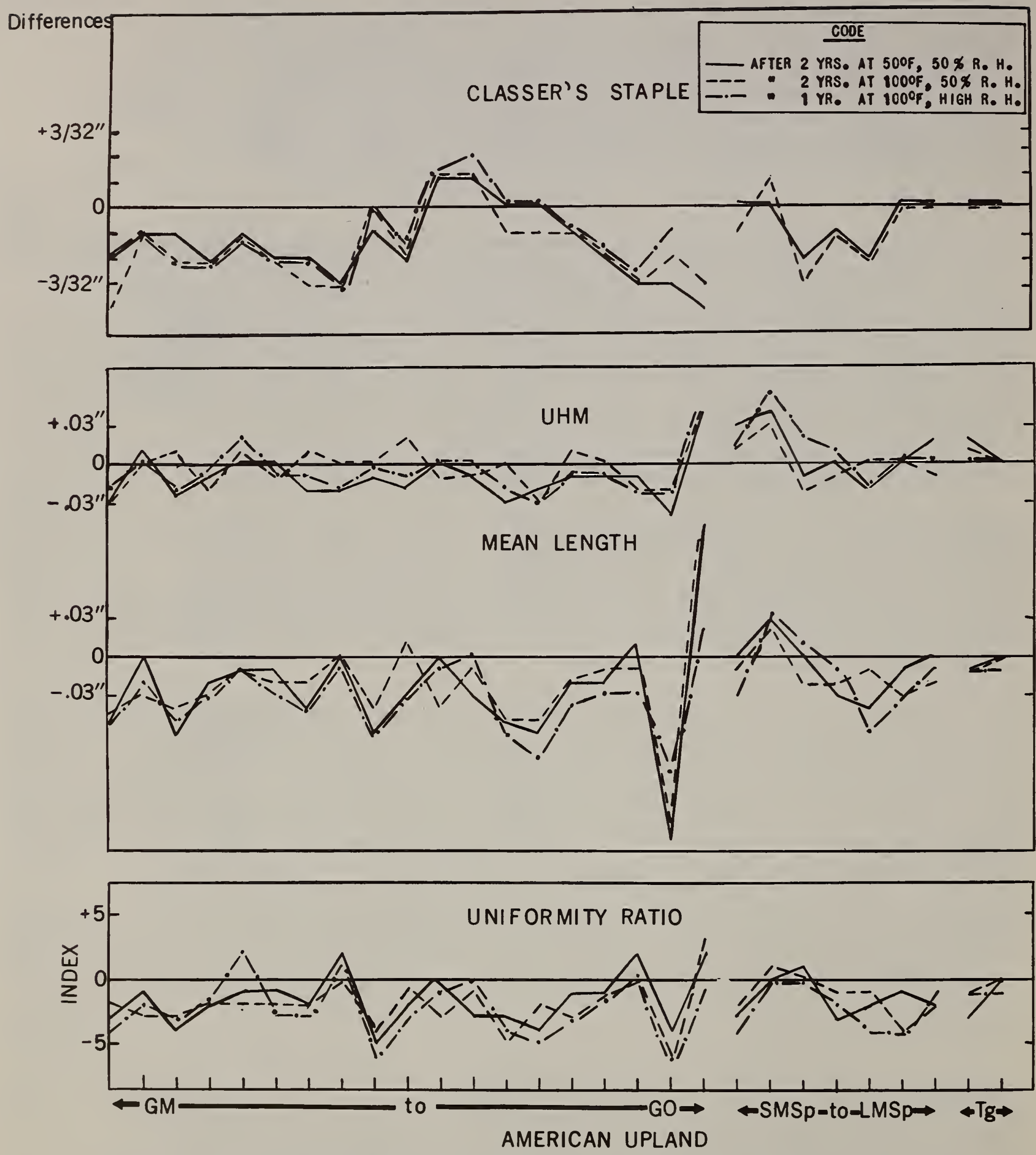


FIG. 1.--MEASUREMENTS ASSOCIATED WITH LENGTH, FOR 28 UPLAND COTTONS BEFORE AND AFTER STORAGE UNDER THREE CONDITIONS. Regardless of storage conditions, cottons after storage seem shorter and less uniform than before storage.

measured shorter. After 100/H storage 13 of 19 white bales measured shorter, but in only one case by as much as 1/32".

Mean length and uniformity measurements for the white grades were quite consistently lower after storage, regardless of storage conditions, with more large individual differences for the 100/H storage conditions. The average decrease in mean length was 0.03" for the white grades. For the colored grades, the trend of change is in the same direction, but not to the same degree.

On the American Egyptian cottons, length measurements by array and Fibrograph methods tend to check each other. Results show no real trend, for the averages show a slight loss for cottons stored at 100/50, and an equally slight gain for storage at 100/H. The two methods did not check on uniformity results. The array method indicated no trend toward change, but uniformity by the Fibrograph method showed consistent loss after storage, even a distinct trend, unlike that for Upland cottons, for more change after 100/H storage than for 50/50 conditions. Differences in mean length by array averaged no change, but mean length by Fibrograph averaged a loss of 0.03" or more, regardless of storage conditions.

<u>Fiber fineness and maturity</u>. Micronaire readings on Upland cottons show no consistent or significant differences after storage, regardless of conditions. For American Egyptian cottons, all differences recorded were in a plus direction, but no greater number of differences occurred for one storage condition than for another.

Causticaire-fineness readings for the white grades were all higher after storage except for two of the lowest grades, but for the colored grades all but one sample showed a decrease. There seemed no trend or relation to conditions of storage. Changes in the American Egyptian cottons seemed to follow a random distribution.

Causticaire maturity measurements for the white grades were practically all lower, and those for the colored grades and the American Egyptian samples were higher after storage, with no apparent relation to the conditions of storage.

<u>Fiber strength</u>. While the precision of this test is not sufficient to be sure of before-and-after storage results that are no more definite than the scatter of results shown in this study, it does seem quite definite that the 1/8" gauge measurements show lower strength for Upland cottons stored at 100/50 than for those stored at 50/50, and that this same trend is shown by 0 gauge measurements of the higher grade white cottons. Since measurements on the samples stored at 50/50 and 100/50 were made at the same time, and since for 27 out of 28 of the Upland cottons the strength was lower for samples stored under 100/50 than under 50/50, it does seem as if there are effects of storage on fiber strength that could be found if only we had more precise methods of measuring fiber strength.

Nonlint by Shirley Analyzer. While the average differences for nonlint content after storage are all on the plus side, there is considerable variation among individual bales, and no evidence of any real trend. Since most of the differences reported are within the standard error of testing ($\pm$ 0.4), it is doubtful whether any significant changes in nonlint content are associated with storage conditions within the range of this study.

Sugar content. For 50/50 and 100/50 storage conditions there seems to be a small but consistent decrease in sugar content, with a consistently larger decrease that reaches zero for most cottons held in storage at 100/H.

The reducing-substance content, called "sugar content" in these studies, usually is high for colored cottons. For example, when tinged cottons first open they measure high in sugar content, thus indicating the immaturity that results from premature opening. For such cottons a high relationship is found between color and sugar content. 2/ If, on the other hand, color is induced during storage there is no accompanying increase in sugar content, and the color-sugar content relationship found for new season cottons no longer holds. On the contrary, when cottons are heated they will decrease in sugar content, as noted by Dr. Paul Marsh, USDA microbiologist at Beltsville, Maryland, in reporting 3/ results of an examination of samples from these tests. He suggests that a similar decrease can be observed by heating cottons for as little as 10 minutes at 160° C.--the color increases, but the reducing sugar decreases. After examination of samples taken from the 50% R.H. storage tests, Dr. Marsh reported that "the difference in (sugar) content between the high and low temperature series seems to us to be entirely reasonable in the sense that oxidation is taking place faster at the higher temperature."

Reduction in sugar content by oxidation is not as well known as a cause of decrease in sugar content as is fungus activity. It is well known that if there is a fungus growing on cotton, the first thing it does is to reduce the sugar content to zero. Therefore, when any measurable amount of sugar is left in samples after storage--as there is for the cottons in this test that were held at 50% R.H.--it is evidence that very little fungal growth occurred.

For samples stored at the higher humidity, 100/H, the sugar content was

---

2/ Normally opened cottons of high grade average about 0.3 sugar content. As these cottons are exposed in the field, they are exposed to microbiological action by various fungi. As a fungus grows on the cotton, the sugar content is gradually reduced until in low grades--whether of white, spotted, or tinged--it reaches zero.

3/ Letter report from Paul Marsh Sept. 29, 1960.

in almost every case reduced to zero. This, combined with the fact that the pH number increased, and the color yellowed about the same amount but darkened more for the cottons held at the higher humidity, is an indication of fungus activity during storage at 100/H.

Acid Alkaline value. The pH of cottons stored at 50/50 and 100/50 shows a small average decrease, but under 100/H practically all of the cottons show an increase, the Upland cottons to a greater degree than the American Egyptian cottons.

A pH value of 7.0 represents the neutral point between acidity and alkalinity. Cottons of high grade, as they come into the market before exposure to microbial action, usually measure a pH of 7.0 or less. Low grade cottons, as they come into market each season usually measure a pH greater than 7.0. Marsh (10) has discussed the reasons for this in some detail. His tables show pH measurements on single bolls, at zero days exposure, that vary from 6.6 to 7.5. When exposed to no rain or heavy dew, the pH remains low (one series of 8 bolls on the 12th day of exposure averaged 6.6 pH as compared to 6.8 pH at 0 days), but when exposed to moisture the pH increases (after successive rains, one set of bolls averaged 9.8 on the 5th day of exposure as compared to 7.2 at zero days exposure). On fibers for which controls measured 6.3 pH, inoculation with 22 varieties of fungus resulted in an increase in pH for all but three varieties. 4/ Exposure to weather and moisture usually causes microbial damage that for most cases results in pH values that vary from 7.0 to 9.0, or even more.

Measurements of pH made in 1954 by Dr. Marsh on 2,350 samples from color survey samples currently received from all major U. S. cotton producing areas uncovered a very definite relationship between pH and grade; 14 GM's averaged 6.6 pH; 82 SM's, 6.6 pH; 138 M's, 6.8 pH; 134 SLM's, 7.5 pH; 89 LM's, 8.1 pH; 23 SGO's, 7.8 pH; and 3 GO's, 7.9 pH. The pH value, measured when the cotton was received, does not remain stable. Microbial action, if there is enough humidity to encourage it, usually causes an increase in pH, but under drier conditions that are unfavorable to microbial growth, the pH may decrease, this decrease being greatest for samples of high pH. Marsh illustrates this by reporting retests on 195 samples held 30 weeks. His results suggest that significant pH differences among samples at time of harvest may lessen, or disappear during dry storage, with all samples tending to become not only lower, but also more nearly the same pH in storage.

4/ Cottons inoculated with Aspergillus niger, and two types of Diplodia, decreased in pH to about 5.0 in the week following incubation. Since each of these fungi is very dark in color, cottons infected with them would quickly result in lowered grades by reason of dark color.

The pH data in this 38-bale test accords with what might be expected on the basis of the Marsh studies. At the beginning of this test the pH of the Upland cottons averaged 7.1 for the white cottons, 6.1 for the colored cottons, and 6.2 for the American Egyptian cottons. Under storage at 50% relative humidity, there was no very sure change at 50° F., if there was one it tended to be a decrease, but at 100° F. there is sure evidence of a decrease in pH. On the other hand, at 100° F. but at a higher humidity, there is a very definite increase in pH.

After reviewing these results in the light of the Marsh studies, and after discussing them with M. E. Whitten, 5/ of the Market Quality Research Division, it seems as if the decrease in pH found for the 50% relative humidity conditions, may indicate a partial oxidation of sugars to sugar acids, causing the pH to be more acid, while the increase in pH found for the higher humidity conditions undoubtedly is related to microbial action.

If this is so, then by a study of the combination of color, sugar, and pH we should be able, at least for some cottons, to tell whether the cotton is old or new, and something about the conditions to which it has been exposed. For example, a sample that is the color of a high grade spot or tinge, if it is a normal sample from a new crop, should have a sugar content of 0.3 or more, and a pH of 7.0 or less. If a sample of this color has a pH around 7.0 or less, but a sugar content close to zero, it seems probable that such a cotton owes its color to oxidation in storage, a change that could have been rapid under high heat, or slower at lower temperatures. At the higher humidities, in which microbial activity takes place, the color, while it will continue to increase in yellowness, often will be darker because of the microbial action, the sugar will decrease to zero, and usually the pH will increase considerably. The relationships found in this study, and in those of Marsh, indicate that it might be profitable to make studies under a number of controlled storage conditions, of cottons carefully measured for color, pH, sugar, strength, and length within a few weeks after harvesting, and at periodic intervals thereafter. (As reported in Section II of this report, this has been done only for color, with a few samples tested for pH and sugar.)

<u>Manufacturing waste</u>. A small but quite consistent increase occurs in manufacturing waste in Upland cottons, regardless of storage conditions, but changes for the American Egyptian cottons seem neither as large nor as consistent. The significance of these changes is somewhat uncertain since many are within the standard error of test reproducibility ($\pm$ 0.8).

<u>Neps</u>. After storage there seem to be fewer neps in the card web, regardless of storage conditions. The average decrease for the white

---

5/ Chemist, working with related problems in cottonseed.

Upland and American Egyptian cottons is small (1 to 6), but for the colored cottons it is enough to be significant (8 to 11).

Yarn strength. In practically all cases, yarns made from stored cottons were lower in strength than yarns made at the beginning of the test from the same cottons. While strength of cottons stored 1 year or less at 100/H was not always lower than cottons stored 2 years under 100/50, a definitely lower strength--as much as 5 pounds for 22s yarns, 7 pounds for the shorter cottons spun into 8s--was found for cottons stored at 100/50 as compared to those stored at 50/50. Since cottons held in these two conditions were stored the same length of time, and processed and measured at the same time, there can be little question about the significance of the results. Yarn strength differences in American Egyptian cottons were not as large, but they were definite, and in the same direction (an average loss of 2 pounds at the 40-pound test level of the American Egyptian cottons represents a 5% loss).

Strength results are shown in figure 2 for yarns and fibers of each of the 28 American Upland cottons to demonstrate the very considerable relationship between strength of fiber and yarns as it is affected by storage conditions under which cotton is held prior to spinning. Certainly the 1/8" gauge measurements foretell the lower yarn strength for cottons held 2 years at 100°, even at a 50% relative humidity, when compared to cottons held at 50/50. The yarn strengths of cottons held for only 1 year at 100° F. and higher humidity (85-90%) are lower than those held at 50/50, but not always lower than those held twice as long under the same temperature but a lower relative humidity (50%). While fiber strength measurements, considered by themselves are not too definite, they become more significant when considered in relation to test results of yarn strength. Figure 2 is presented so that all of the results relating to strength may be considered together.

Yarn appearance. After storage under 50/50 conditions for 2 years Upland cottons showed no significant change in appearance for 8s or 22s yarns (of 10 rating changes 6 were up, 4 down), but for 10 rating changes made on 50s yarn, all were down. On the other hand, after storage at 100/50 conditions, appearance ratings for 22s yarns showed improvement for all 11 changes made in rating white bales, and for all but 1 of 6 colored bales. Improvement in appearance was consistent for all rating changes on 8s and 22s yarns made from cottons stored under 100/H conditions, yet for 50s yarns, all changes but one indicated a lower appearance rating, with a few more changes made after storage at high as compared to medium humidity. For American Egyptian cottons the majority of all changes in appearance rating indicated improvement after storage, regardless of conditions.

Taking into consideration the small but consistent increase noted in manufacturing waste of stored cottons, and the small but consistent decrease in neps, the small but apparently consistent improvement in appearance of 8s and 22s yarn may be associated with these factors as they are affected by storage.

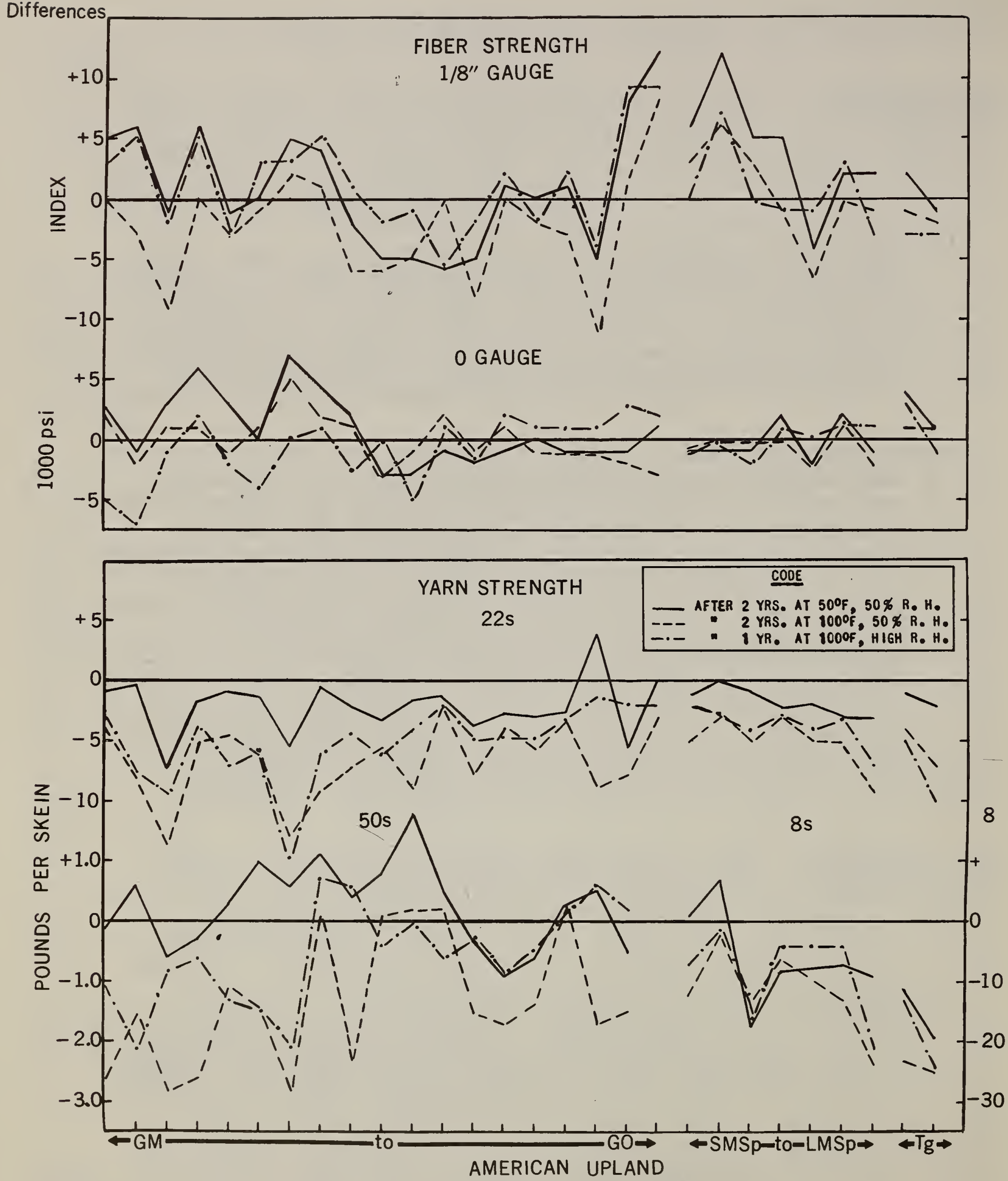


FIG. 2.--MEASUREMENTS ASSOCIATED WITH STRENGTH, FOR 28 UPLAND COTTONS BEFORE AND AFTER STORAGE UNDER THREE CONDITIONS. Note similarity of trend for fiber and yarn strength to be lower for cottons stored at 100° F. than for cottons stored at 50° F.

Color of raw stock. The color of raw stock, as measured in terms of percent reflectance and yellowness, and a color index (similar in level to the grade index but converted from color measurements instead of from classer's grade), all show a very high relationship of color change with condition of storage. Cottons stored 2 years under 50/50 conditions show little or no color change. Cottons stored 2 years under 100/50 show considerable change, with more change in the high grades of Upland cottons than in the low grades. Cotton stored under 100/H conditions show as much, or even more change after 1 year of storage as cottons stored twice as long under 100/50 conditions. These cottons not only yellowed as much or more than cottons held at a lower humidity, but they darkened more than similar cottons held under 50% relative humidity. And this darkening is evidence of microbiological activity as well as of a chemical change, such as oxidation, that undoubtedly takes place with time, and at a rate that increases with temperature. The microbiological activity seems to have been less in the white grades than in the spotted and tinged grades. This is clearly shown in figure 3 by the relatively greater darkening of color for the colored grades held at 100/H.

Translated into price differences, using the grade-color code (11) to translate color changes into equivalent grade changes, and based on 1960 loan premiums and discounts (as used for prices reported for grade changes), there was no loss for Upland cottons stored at 50/50 conditions, a loss of 114 points for American Egyptian cottons. For storage under 100/50 white grades averaged a loss of 115 points, colored grades 258 points, and American Egyptian grades 489 points. For storage under 100/H, even for a shorter time, The equivalent loss for the white grades was 280 points, for colored grades 471 points, and American Egyptian grades 963 points after only 6 months storage.

Color measurements, averaged by grades forthe original cottons before storage, and for the same cottons after storage, are shown in figure 3 against color diagrams of the grade standards. These show very large color changes for 2 years at 100/50 and 1 year at 100/H storage, yet under 50/50 conditions a minimum of change occurs for the same samples. The color changes reported for these cottons substantiate fully the pattern of change that has been reported previously.

Color of grey yarn. The color of grey yarn is dependent on the color of the cleaned lint from which it was made and, except for unusual combinations of color, leaf, and preparation in a sample, should show a close relationship to color measurements of raw cotton. This expected close relationship is apparent in the results for these samples. The level of measurements for R_d and b differs because of difference in the physical form of lint and yarn, but the changes that result from storage under the several test conditions are of the same order in both lint and yarn.

The index for these grey yarns after storage, particularly for the Upland cottons, must be used with care, for it could be misleading.

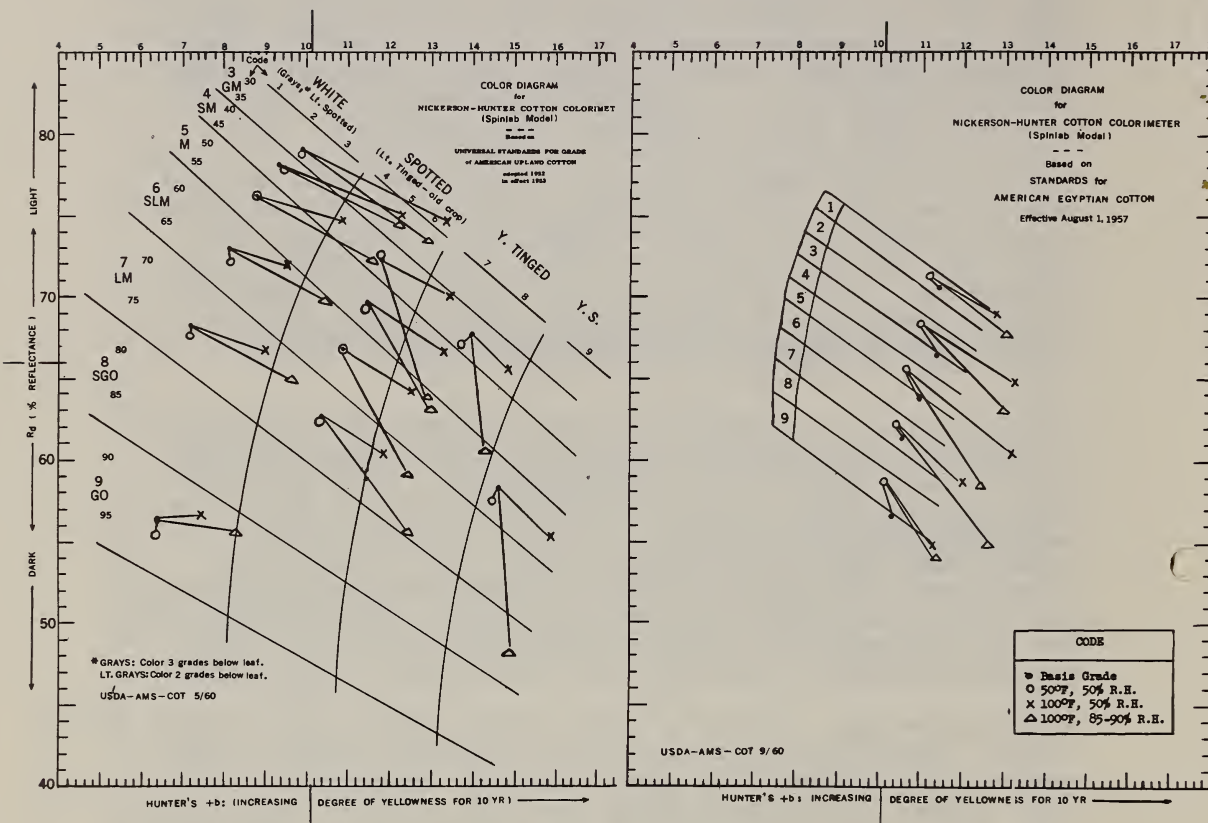


Fig. 3.--Color measurements before and after storage of 28 samples representing 12 grades of Upland cottons averaged by grades and 10 bales representing five grades of American Egyptian cottons. Color changes are very small for 2 years at 50° F., 50% R.H. but are large for 1 year at 100° F., 85-90% R.H. and 2 years at 100° F., 50% R.H.

It was developed to apply to the color of cottons as they normally come to market. There is no equivalent color in new crop cottons to the deepened color caused by storage of the higher grades, and the index is based on the normal color range of the crop. For convenience, and in order to have a single number for comparison of one grey yarn with another, the index that applies to the regular samples is reported, but its meaning in terms of amount of grade change no longer holds because the samples already have changed in color so much in storage that they must be read from a part of the diagram that does not apply to the normal condition.

Color of bleached yarns. As color measurements indicate, the color of bleached yarns is dependent on the color of the grey yarns, While the color differences are smaller (samples are bleached to make them as uniformly white as possible, so that they will dye as evenly and deeply as possible), nevertheless differences in raw stock and grey yarn color follow through to the bleached yarns: cottons stored at 50/50 bleach about the same as the original samples; the color gained by cottons during storage at 100/50 does not bleach out to the level of the original; and the even yellower color of samples stored at 100/H remains yellower after bleaching than samples stored at 100/50.

The preparation of yarns for color measurement, particularly of white samples in which there are shadow irregularities, can cause significantly poorer precision of measurement than the preparation of darker samples, or of samples prepared and measured in a different physical form. While the reproducibility of measurements of bleached yarn color due to its dependence on sample preparation, leaves something to be desired, nevertheless, the results show that in the bleached yarns, samples hold the same relative position they held in the grey yarn series, not only do the lower grades produce lower color in bleached yarns, but the yellower colors in the grey yarns remain the yellower colors in the bleached yarns. Even a small amount of yellowing can be important in bleached yarns, and whether the average eye can see this or not, it becomes important in the uniform dyeing and finishing of cottons.

Color of dyed yarns. A medium dark blue is used in USDA finishing tests for dyeing. In these tests the color of the dyed yarns shows that even after bleaching, the color differences in the raw stock (whether caused by differences in grade due to exposure or harvesting, or due to color changes during storage) follow through to the dyed product.

High grade white cottons bleach the whitest and dye the deepest, in this case, the deepest blue. Low grade, dark cottons take less dye and appear a faded blue. Cottons that originally may have been a high grade white, but have gained yellow color during storage, do not dye as deep a blue as the original unyellowed cottons.

The color index for white cottons dyed after storage for 2 years at 100/50 is 6 points lower than for the same cotton stored at 50/50, after storage at 100/H it is 12 points lower, equivalent to a price difference of 280 points. For the colored Upland grades, and the American Egyptian grades, the differential is as great or greater. While there seems to have been an improvement in dyeing Upland cottons that were held in storage without change in color of raw stock, it is not certain whether this represents the facts, or whether it may be based on a difference in level of testing, for the reproducibility of color levels from one dye bath to another, and the preparation of yarn samples for color measurement (as already noted for bleached yarn measurements) lack the precision we would like for these tests. Controls are used, and efforts at improvement are being made. The tests made after 2 years storage were made at the same time, and on these paired comparisons we may rely fully. Whether the improvement indicated after 1 year of storage at 50/50 is real, or is caused by a difference in level of testing for tests made 2 years apart, the first test made before there had been much experience with it, is questionable.

Luster of 50s combed yarn. While luster measurements have been made on grey and mercerized yarns made from the American Egyptian cottons in this test, it is believed that the differences shown for luster are more significantly related to differences in levels of color than to any real difference in luster itself.

Summary and Conclusions

Differences in grade, color, strength, sugar, pH, and color of bleached and dyed yarns are found before and after storage in a study of 38 bales of cottons that cover the range of grades in American Upland and American Egyptian cottons. The amount of difference in these factors is found to be dependent upon the time and conditions of storage; little difference occurred after storage for 2 years at 50° F., 50% R.H., but some differences were large after storage for 2 years at 100° F., 50% R.H., and even larger after storage for a shorter period at the same temperature but at a higher humidity. The grade change, translated into price differences, indicates differences that average up to 280 points for white grades (as much as 370 to 380 points for GM and SM), almost 500 points for the colored grades, and nearly 1,000 points for American Egyptian grades.

Staple differences, which seem to occur regardless of the conditions of storage, average as much as 1/16" shorter after storage, with less change for short than for longer cottons. Instrument measurements support this change in direction, though not in degree. UHM length changes are small, but Fibrograph mean length for the white and American Egyptian cottons averages about 0.03" shorter after storage, with the results that there is a significant increase in Fibrograph measurements of uniformity ratio.

There seems an indication of a tendency toward improvement in appearance rating after storage, not entirely consistent, but probable, if one takes into consideration that there is evidence of a small but consistent

increase in waste of stored cottons, and a small but consistent decrease in neps.

No consistent or significant differences were found after storage for measurements of fineness and maturity.

Differences in finishing properties, as evidenced by bleached and dyed color of yarns, are directly related to changes in raw stock color. The color differences that occur for storage under 100° F. are as much as the difference from White to Spotted grades or Spotted to Tinged grades, and these differences follow through to show up as differences in finishing tests. No measure of dyeing uniformity is included in this study, but it is an important consideration. Even very small color differences in dyeing are important, for the eye is extremely critical, and unevenness of color, or dyeing differences that result in skeins that differ only enough to cause uneven color in a woven fabric will cause the woven material to be classed as a "second."

On the basis of the 38 bales in this test there is not sufficient information to establish the amount of change that may be expected in the several factors that seem to change differentially under different storage conditions, as has been done for color on the basis of a 3-year test under different storage conditions, but it does seem clear that such a pattern exists. It also seems clear that the conditions that cause deterioration in color also cause a deterioration in strength, and that sugar and pH changes provide some measure of a part of the cause of these changes. We do not have an explanation of all causes for these changes, but as a result of this study it seems certain that the changes exist and that many of them are related.

Literature Cited

(1) Nickerson, D.
1951. Effect of exposure and storage on color and other factors of quality in raw cotton. USDA (PMA 318), 27 pp. (Jan.)

(2) Haury, E. W. and Conrad, C. M.
1938. The comparison of fiber properties of Arizona Cliff-Dweller and Hopi cotton. American Antiquity 3:224-227, illus.

(3) Hawkins, R. W. and Thomas, W. F.
1948. The effect of moisture content, field exposure, and processing on the spinning value of Arizona Upland cotton. Ariz. Agr. Exp. Sta. Tech. Bull. 115, pp 249-292, illus.

(4) Ahmad and Gulati.
1944. The effect of storage under certain specified conditions on the quality of Indian cottons. Indian Central Cotton Committee Tech. Lab. Tech. Bull. Series B, No. 31.

(5) Nickerson, D.
1933. Grade of cotton affected by exposure in the field. U. S. Dept. Agr. 12 pp.

(6) Grimes, M. A.
1936. The effect of exposure in the field on grade, strength and color of raw cotton. Texas Agr. Exp. Sta. Bull. 538, 35 pp., illus.

(7) Nickerson, D. and Tomaszewski, J. J.
1958. Color change in raw cotton related to conditions of storage. Text. Res. Jour. XXVIII. 485-497.

(8) Nickerson, D. and Tomaszewski, J. J.
1958. Sugar, pH, and strength changes in cotton during storage. Text. Res. Jour. XXVIII. 528-9.

(9) Nickerson, D. and Tomaszewski, J. J.
1959. Cotton Grade Studies, No. 4. Color Change in Storage. Mimeo., Cotton Div., for use at 1959 Universal Grade Standards Conference.

(10) Marsh, P. B. et al.
1951. The influence of weathering and of microorganisms on the aqueous-extract pH of cotton fibers. Text. Res. Jour. XXI. pp. 565-579. (Aug.)

(11) United States Department of Agriculture.
1960. Color code for relating measurements of raw cotton to color in grade standards. U.S. Dept. Agr., AMS-411, 4 pp. (Oct.)

APPENDIX A.--Cottons from 28 American Upland grade standards bales stored under controlled conditions of temperature and humidity, measurements before storage and differences after storage for 28 classification, fiber, yarn, and finishing tests

Grade and position	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	1. CLASSER'S GRADE (Index)				2. CLASSER'S STAPLE (32nds")			
	Index	Differences			(32nds")	Differences		
GM-2	105	0	-4	-4	36	-2	-4	-2
3	105	-1	-4	-4	34	-1	-1	-1
4	105	0	-4	-4	36	-1	-2	-2
5	105	-2	-4	-4	36	-2	-2	-2
SM-1	104	0	-2	-3	35	-1	-1	-1
3	104	0	-5	-3	35	-2	-2	-2
4	104	0	-3	-3	36	-2	-3	-2
6	104	0	-3	-3	36	-3	-3	-3
M-1	100	0	0	-1	35	-1	0	0
3	100	0	-3	-1	34	-2	-2	-1
4	100	+4	-1	-1	33	+1	+1	+1
5	100	0	0	-1	31	+1	+1	+2
SLM-1	94	0	0	-1	34	0	-1	0
LM-1	85	0	0	-10	34	0	-1	0
4	85	0	+4	-2	34	-1	-1	-1
5	85	0	0	-10	34	-2	-2	-2
GO-4	70	0	0	0	34	-3	-3	-3
3	70	0	0	0	34	-3	-2	-1
6	70	0	-10	0	34	-4	-3	
Average	94	0	-2	-3	34	-2	-2	-1
SMSp-W	99	0	-8		31	0	-1	
" Y	99	-6	-17		28	0	+1	
MSp-W	93	0	-11		33	-2	-3	
" Y	93	0	-11		32	-1	-1	
SLMSp-W	83	-8	-8	-15	35	-2	-2	-2
" Y	83	-8	-15		31	0	0	
LMSp-W	75	0	0		28	0	0	
SMT-Y	91	0	0		29	0	0	
SLMT-Y	75	-7	-15		28	0	0	
Average	88	-3	-9		31	-1	-1	

APPENDIX A.--(Continued)

Grade and position	Measurements							
	Before storage	After storage for			Before storage	After storage for		
		2 years at		1 year at		2 years at		1 year
		50°/50%	100°/50%	100°/85%		50°/50%	100°/50%	100°/85%
	2a. GRADE AS CLASSED				2b. 1960 LOAN PREMIUMS & DISCOUNTS (1") FOR GRADES AS CLASSED			
					Pts.	Pts.	Pts.	Pts.
GM-2	GM	GM	GM Sp	GM Sp	70	70	-310	-310
3	GM	SM	GM Sp	GM Sp	70	60	-310	-310
4	GM	GM	GM Sp	GM Sp	70	70	-310	-310
5	GM	GM LtSp	GM Sp	GM Sp	70	-105	-310	-310
SM-1	SM	SM	SM LtSp	GM Sp	60	60	-125	-310
3	SM	SM	SM Sp	GM Sp	60	60	-330	-310
4	SM	SM	GM Sp	GM Sp	60	60	-310	-310
6	SM	SM	GM Sp	GM Sp	60	60	-310	-310
M-1	M	M	M	SM Sp	0	0	0	-330
3	M	M	M LtSp	SM Sp	0	0	-285	-330
4	M	SM	SM Sp	SM Sp	0	60	-330	-330
5	M	M	M	SM Sp	0	0	0	-330
SLM-1	SLM	SLM	SLM	M Sp	-280	-280	-280	-560
LM-1	LM	LM	LM	LM Sp	-525	-525	-525	-1045
4	LM	LM	SLM LtSp	SLM Sp	-525	-525	-525	-800
5	LM	LM	LM	LM Sp	-525	-525	-525	-1045
GO-4	GO	GO	GO	GO	-1010	-1010	-1010	-1010
3	GO	GO	GO	GO	-1010	-1010	-1010	-1010
6	GO	GO	BG	—	-1010	-1010	-1200	—
Av.					-284	-289	-421	-515
Diff					Orig.	-5	-137	-231
SM Sp-W	SM Sp	SM Sp	SM Tg	—	-330	-330	-860	—
" Y	SM Sp	M Sp	M Tg	—	-330	-560	-1020	—
M Sp-W	M Sp	M Sp	M Tg	—	-560	-560	-1020	—
" " Y	M Sp	M Sp	M Tg	—	-560	-560	-1020	
SLM Sp-W	SLM Sp	LM Sp	LM Sp	LM Tg	-800	-1045	-1045	-1380
" " Y	SLM Sp	LM Sp	LM Tg	—	-800	-1045	-1380	—
LM Sp-W	LM Sp	LM Sp	LM Sp	—	-1045	-1045	-1045	—
SMT-Y	SM Tg	SM Tg	SM Tg	—	-860	-860	-860	—
SLMT-Y	SLM Tg	LM Tg	BG	—	-1210	-860	-1200	—
Av.					-722	-763	-1050	-1380*
Diff.					Orig.	-41	-328	-658**

* Estimated

** Estimated

APPENDIX A.--(Continued)

Grade and position	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	3. FIBROGRAPH, U.H.M. LENGTH				4. FIBROGRAPH, UNIFORMITY RATIO			
	(Inches)	Differences			(Percent)	Differences		
GM-2	1.04	-0.03	-0.03	-0.02	85	-3	-2	-4
3	.99	+ .01	0	0	82	-1	-3	-2
4	1.10	- .02	+ .01	- .02	84	-4	-3	-3
5	1.09	- .01	- .02	- .01	83	-2	-2	-2
SM-1	1.04	0	+ .01	+ .02	77	-1	-2	+2
3	1.03	0	- .01	- .01	82	-1	-2	-3
4	1.09	- .02	+ .01	- .01	84	-2	-2	-3
6	1.06	- .02	0	- .02	81	+2	0	+1
M-1	1.11	- .01	0	0	83	-5	-4	-6
3	.98	- .02	+ .02	- .01	81	-2	-1	-3
4	1.06	0	- .01	0	81	0	-3	-1
5	.98	- .01	- .01	0	80	-3	-1	0
SLM-1	1.10	- .03	0	- .02	83	-3	-5	-4
LM-1	1.08	- .02	- .03	- .03	81	-4	-2	-5
4	1.04	- .01	+ .01	- .01	81	-1	-3	-3
5	1.01	- .01	0	- .01	81	-1	-1	-2
GO-4	1.00	- .01	- .02	- .02	79	+2	0	0
3	1.08	- .04	- .02	- .02	81	-4	-6	-6
6	.94	+ .04	+ .04	+ .04	74	+2	+3	-4
Average	1.04	-0.01	0	-0.01	81	-2	-2	-2
SMSp-W	0.93	+0.03	+0.01	+0.01	81	-3	-2	-4
" Y	.80	.04	.02	.04	76	0	+1	0
MSp-W	.96	- .01	- .02	.02	79	+1	0	0
" Y	.94	0	- .01	.01	83	-3	-1	-2
SLMSp-W	1.10	- .02	0	- .02	83	-2	-1	-4
" Y	.92	0	0	0	84	-1	-4	-4
LMSp-W	.75	+ .02	- .01	0	80	-2	-2	-1
SMT-Y	.86	.02	+ .01	0	78	-3	-1	-1
SLMT-Y	.82	0	0	0	79	0	0	-1
Average	0.90	+0.01	0	+0.01	80	-1	-1	-2

APPENDIX A.--(Continued)

Grade and position	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
		(American Upland)		
		3a. FIBROGRAPH, MEAN LENGTH		
GM-2	0.88	-0.05	-0.04	- .05
3	.81	0	- .03	- .02
4	.92	- .06	- .04	- .05
5	.90	- .02	- .03	- .03
SM-1	.80	- .01	- .04	- .04
3	.84	- .01	- .02	- .03
4	.92	- .04	- .02	- .04
6	.86	0	0	- .01
M-1	.92	- .06	- .04	- .06
3	.79	- .03	+ .01	- .03
4	.86	0	- .04	- .01
5	.78	- .03	- .01	—
SLM-1	.91	- .05	- .05	- .06
LM-1	.88	- .06	- .05	- .08
4	.84	- .02	- .02	- .04
5	.82	- .02	- .01	- .03
GO-4	.79	+ .01	- .02	- .03
3	.88	- .14	- .13	- .09
6	.70	+ .10	+ .09	+ .02
Average	0.85	-0.03	- .03	-0.03
SMSp-W	.75	0	- .01	-0.03
" Y	.61	+ .03	+ .02	+ .03
MSp-W	.76	0	- .02	+ .01
" Y	.78	- .03	- .02	- .01
SLMSp-W	.91	- .04	- .01	- .06
" Y	.77	- .01	- .03	- .03
LMSp-W	.60	0	- .02	- .01
SMT-Y	.67	- .01	- .01	- .01
SLMT-Y	.65	0	0	- .01
Average	.72	- .01	- .01	- .02

APPENDIX A.--(Continued)

Grade and position	Measurements: 5. MICRONAIRE (Reading) — Before storage (Reading)	After storage for 2 years at 50°/50% — Differences	After storage for 2 years at 100°/50% — Differences	After storage for 1 year at 100°/85% — Differences	6. CAUSTICAIRE-FINENESS (ug/inch) — Before storage (ug/inch)	After storage for 2 years at 50°/50% — Differences	After storage for 2 years at 100°/50% — Differences	After storage for 1 year at 100°/85% — Differences
GM-2	4.8	0	-0.2	-0.2	4.6	+0.3	+0.4	+0.2
3	4.3	-0.1	- .1	+ .1	4.3	.1	.3	.2
4	4.3	+ .3	+ .1	.1	4.0	.6	.6	.3
5	4.2	- .2	- .1	- .1	4.0	.2	.3	.1
SM-1	4.2	0	0	+ .2	4.1	.2	.3	.2
3	4.4	0	0	.1	4.3	.2	.5	.2
4	4.8	0	0	0	4.6	.4	.3	.2
6	4.5	+ .3	+ .1	+ .2	4.5	.3	.3	.3
M-1	4.4	0	0	.1	4.3	.3	.3	.3
3	4.0	+ .2	- .1	0	3.8	.5	.7	.2
4	4.5	0	0	+ .1	4.3	.3	.2	.3
5	5.2	0	0	0	5.1	.3	.4	.3
SLM-1	4.4	0	0	0	4.2	.2	.4	.3
LM-1	3.8	+ .2	+ .2	0	3.5	.4	.6	.2
4	3.8	0	0	0	3.8	.1	.2	.1
5	4.4	0	0	0	4.1	.4	.5	.3
GO-4	3.0	+ .2	+ .2	+ .2	2.8	.4	.5	.3
3	3.7	- .1	- .1	.1	3.8	- .1	- .1	- .1
6	4.0	- .1	0	- .2	4.2	- .4	- .3	- .4
Average	4.2	0	0	0	4.1	+0.2	+0.3	+0.2
SMSp-W	4.0	+0.2	+0.2	0	4.7	-0.3	-0.5	-0.5
" Y	4.2	0	0	-0.2	4.6	- .3	- .4	- .5
MSp-W	4.0	0	0	0	4.2	- .1	- .1	- .2
" Y	5.0	+ .2	+ .2	0	5.6	- .5	- .5	- .5
SLMSp-W	4.3	+ .1	- .1	0	4.2	+ .4	+ .6	+ .2
" Y	3.8	- .1	0	0	4.4	- .5	- .5	- .8
LMSp-W	4.6	- .2	- .1	- .1	4.8	- .3	- .5	- .4
SMT-Y	4.7	0	+ .1	- .1	5.1	- .4	- .3	- .4
SLMT-Y	3.2	+ .2	+ .2	+ .2	3.7	- .2	- .3	- .3
Average	4.2	0	+0.1	0	4.6	-0.2	-0.3	-0.4

APPENDIX A.--(Continued)

Grade and position	7. CAUSTICAIRE-MATURITY: Before storage (Index)	Differences: After storage for 2 years at 50°/50%	Differences: After storage for 2 years at 100°/50%	Differences: After storage for 1 year at 100°/85%	8. PRESSLEY STRENGTH, 0 Gage: Before storage (1,000 psi)	Differences: After storage for 2 years at 50°/50%	Differences: After storage for 2 years at 100°/50%	Differences: After storage for 1 year at 100°/85%
GM-2	82	-2	-4	-2	77	+3	+2	-5
3	79	-1	-3	-1	84	-1	-2	-7
4	81	-1	-3	-2	88	+3	+1	-1
5	80	-3	-4	-2	81	6	1	+2
SM-1	80	-1	-3	-1	77	3	-1	-2
3	80	-1	-2	-1	86	0	+1	-4
4	82	-2	-1	-1	93	7	5	0
6	80	+1	-1	0	75	4	2	+1
M-1	80	-1	-2	-1	73	2	1	-2
3	79	-2	-6	-2	86	-3	-3	0
4	82	-3	-2	-3	88	-3	-1	-5
5	83	-1	-3	-1	68	-1	+2	+1
SLM-1	80	0	-3	-2	78	-2	-1	-2
LM-1	79	-1	-2	-3	78	-1	+1	+2
4	77	-2	-3	-3	82	0	-1	1
5	81	-2	-3	-1	80	-1	-1	1
GO-4	69	+1	+1	+2	85	-1	-1	1
3	76	-1	-2	0	84	-1	-2	3
6	75	+2	+3	+1	86	+1	-3	2
Average	79	-1	-2	-1	82	+1	0	-1
SMSp-W	73	+3	+5	+3	66	-1	-1	-1
" Y	75	2	3	3	82	-1	0	0
MSp-W	75	2	2	2	78	-1	0	-2
" Y	79	4	4	2	72	+2	0	+1
SLMSp-W	80	-1	-4	-1	76	-2	-2	0
" Y	71	+2	+3	+6	74	+2	+1	1
LMSp-W	78	1	3	2	78	-1	-2	1
SMT-Y	78	2	3	2	79	+4	+1	3
SLMT-Y	68	4	5	4	73	1	1	-1
Average	75	+2	+3	+3	75	0	0	0

APPENDIX A.--(Continued)

Grade and position	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	9. PRESSLEY STRENGTH, 1/8" Gage				10. SHIRLEY ANALYZER NONLINT			
	(1,000psi)	Differences			(Percent)	Differences		
GM-2	94	+5	0	+3	1.66	-0.07	-0.30	+0.82
3	92	6	-3	5	1.35	- .06	+ .02	1.12
4	115	-1	-9	-2	1.67	+ .22	- .05	1.08
5	104	+6	0	+6	1.39	- .07	+ .22	.04
SM-1	94	-1	-3	-3	2.25	+ .05	- .03	.36
3	95	0	-1	+3	2.21	.02	+ .18	.48
4	113	+5	+2	3	1.65	- .06	.03	.39
6	93	4	1	5	1.83	+ .07	- .10	.34
M-1	100	-2	-6	1	2.27	.01	- .13	- .02
3	101	-5	-6	-2	3.17	.07	+ .29	+ .25
4	112	-5	-5	-1	2.06	- .05	.16	.01
5	92	-6	0	-6	2.35	- .35	.01	.20
SLM-1	101	-5	-8	-2	3.91	-1.07	- .85	- .25
LM-1	94	+1	0	+2	5.52	- .28	- .10	+ .02
4	103	0	-2	-2	4.90	+ .37	+ .68	1.07
5	97	1	-3	+2	6.58	2.00	2.37	1.07
GO-4	114	-5	-12	-4	7.72	1.55	1.45	1.60
3	98	+8	+2	+9	7.26	.75	2.08	1.06
6	87	12	8	9	9.89	.26	- .54	- .76
Average	100	+1	-2	+1	3.67	+0.18	+0.28	+0.46
SMSp-W	80	+6	+3	0	3.75	-0.96	-0.45	-1.06
" Y	77	12	6	+7	5.22	+ .45	+ .64	+ .65
MSp-W	95	5	3	0	4.77	.06	.05	- .47
" Y	86	5	-1	-1	4.71	.66	.45	+ .26
SLMSp-W	98	-4	-9	-1	5.92	.75	.70	1.10
" Y	89	+2	0	+3	10.38	- .30	- .53	- .19
LMSp-W	86	2	-1	-3	10.62	+ .18	-1.06	- .64
SMT-Y	86	2	-1	-3	4.06	+ .36	+ .83	- .19
SLMT-Y	87	-1	-2	-3	7.85	.24	.75	+ .40
Average	87	+3	0	-1	6.36	+0.16	+0.15	-0.02

APPENDIX A.--(Continued)

Grade and position	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
		11. SUGAR CONTENT				12. ACID-ALKALINE VALUE (pH)		
	(Percent)	Differences			(pH)	Differences		
GM-2	0.2	0	0	-0.2	7.5	-0.7	-1.1	+1.0
3	.3	0	-0.1	- .3	7.0	- .6	-1.0	1.4
4	.6	-0.3	- .3	- .6	5.5	+ .8	+ .4	4.3
5	.5	- .2	- .3	- .5	7.0	- .5	- .9	1.2
SM-1	.3	- .1	- .2	- .3	6.2	+ .2	- .3	3.0
3	.3	- .1	- .1	- .3	6.8	- .2	- .7	2.9
4	.3	0	- .4	- .3	6.7	- .3	- .7	3.0
6	.5	- .2	- .3	- .5	6.8	- .1	- .6	3.2
M-1	.2	0	- .1	- .2	6.7	- .3	- .6	2.0
3	.3	- .1	- .2	- .3	6.8	- .1	- .5	2.4
4	.3	0	- .1	- .3	6.9	- .1	- .6	2.8
5	.2	- .1	- .1	- .2	7.4	+ .2	- .4	0.1
SLM-1	.1	0	- .1	- .1	7.1	- .2	- .5	.8
LM-1	.2	0	0	- .2	7.4	- .6	- .8	1.4
4	.3	- .1	- .2	- .3	7.2	- .4	- .6	2.4
5	.3	- .1	- .2	- .3	7.0	- .2	- .5	.3
GO-4	.3	- .2	- .2	- .3	7.6	+ .5	- .3	0
3	.2	0	- .1	- .2	8.2	- .8	-1.1	- .4
6	0	0	0	0	8.2	+ .1	- .8	- .7
Average	0.3	-0.1	-0.2	-0.3	7.1	-0.2	-0.6	+1.6
SMSp-W	0.3	+0.5	0	-0.3	5.8	+0.8	+0.4	+3.4
" Y	.1	- .1	-0.1	- .1	6.4	- .3	- .4	.7
MSp-W	.6	- .3	- .3	- .5	6.2	+ .2	- .2	3.6
" Y	.2	0	0	- .2	6.2	+ .4	+ .2	3.7
SLMSp-W	.5	+ .4	- .2	- .5	6.7	- .2	- .5	.4
" Y	.2	0	0	- .2	6.0	+ .1	- .4	1.9
LMSp-W	.2	.1	0	- .2	6.0	0	- .1	1.0
SMT-Y	.2	.1	0	- .2	6.0	0	- .1	3.5
SLMT-Y	.5	.3	- .2	- .4	5.8	- .2	- .3	3.0
Average	0.3	+0.1	-0.1	-0.3	6.1	+0.1	-0.2	+2.4

APPENDIX A.--(Continued)

Grade and position	13. Picker waste: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	14. Card waste: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	(Percent)	Differences			(Percent)	Differences		
GM-2	1.14	-0.07	+0.12	+0.26	4.75	+1.64	+1.56	+1.42
3	.60	+ .08	.65	0	5.57	.86	1.11	1.90
4	.60	.26	.10	.91	5.65	2.22	2.01	1.44
5	.60	.51	- .40	.28	4.62	1.63	2.50	2.55
SM-1	1.01	.19	+ .19	.45	6.80	.13	.10	.54
3	.65	.36	.87	1.08	5.75	.85	1.66	1.17
4	.60	.20	.02	1.51	5.39	1.41	.70	1.33
6	.80	.12	.15	.98	5.43	1.39	1.14	1.01
M-1	1.09	.40	.11	.41	5.54	1.83	1.05	1.52
3	.67	1.44	1.07	2.18	6.87	.93	.55	.78
4	1.01	- .57	- .01	.42	5.57	1.67	1.35	2.14
5	.43	+1.00	+1.11	1.02	7.78	.96	1.55	1.62
SLM-1	.65	+ .70	+ .72	1.26	7.16	1.32	.99	1.69
LM-1	1.71	.26	.65	1.02	9.14	.97	.98	- .02
4	1.80	- .51	.46	.82	8.79	.22	- .22	+1.10
5	2.60	+ .39	.41	.80	9.50	.30	+1.66	.74
GO-4	2.60	- .13	- .07	1.35	11.63	- .36	.18	- .29
3	2.43	+ .71	+1.00	.71	11.14	+3.24	1.66	+ .03
6	3.80	.23	.44	.11	10.94	- .07	.02	- .63
Average	1.30	+0.29	+0.40	+0.82	7.26	+1.11	+1.08	+1.06
SMSp-W	0.60	+0.60	+0.60	+1.01	6.92	+0.13	+0.13	+0.50
" Y	2.05	.31	.59	- .05	8.60	1.06	.27	1.36
MSp-W	1.60	.26	.27	+ .29	7.84	.04	- .49	- .21
" Y	2.79	- .72	- .51	- .62	9.41	- .94	- .75	-1.07
SLMSp-W	1.80	+ .20	+ .27	+ .40	8.42	+ .80	+ .72	+ .32
" Y	3.40	.20	.78	.20	11.45	- .17	- .25	.09
LMSp-W	5.00	- .17	- .40	- .40	11.80	- .25	- .40	- .31
SMT-Y	1.89	- .27	+ .01	+ .11	7.71	+ .40	+ .52	+1.57
SLMT-Y	2.79	+ .75	.91	.50	9.41	.66	1.02	2.64
Average	2.44	+0.13	+0.28	+0.16	9.06	+0.19	+0.09	+0.55

APPENDIX A.--(Continued)

Grade and position	Measurements							
	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	15. PICKER & CARD WASTE				16. NEPS IN CARD WEB			
	(Percent)	Differences			(Per 100 sq. in.)	Differences		
GM-2	5.84	+1.55	+1.65	+1.64	11	-5	-3	+1
3	6.14	.93	1.71	1.89	19	-12	-7	-10
4	6.22	2.44	2.09	2.27	18	-4	-2	+1
5	5.19	2.10	2.12	2.80	22	-3	-3	-3
SM-1	7.74	.31	.28	.95	18	-3	-5	-5
3	6.36	1.18	2.46	2.17	18	-8	-3	-7
4	5.96	1.59	.71	2.73	9	+2	+1	+4
6	6.19	1.49	1.27	1.92	13	-5	-4	-1
M-1	6.57	2.18	1.14	1.88	13	0	+3	-1
3	7.49	2.26	1.54	2.79	19	-5	-3	0
4	6.52	1.13	1.33	2.51	16	-4	+1	-4
5	8.18	1.87	2.55	2.53	20	0	-8	-6
SLM-1	7.76	1.96	1.65	2.83	16	0	+4	0
LM-1	10.69	1.19	1.55	.91	34	+6	-2	-9
4	10.43	- .25	.21	1.82	29	-7	-5	-5
5	11.85	+ .70	1.98	1.44	21	0	-5	-6
GO-4	13.93	.42	.11	.91	68	-17	-22	-42
3	13.30	3.77	2.49	.66	49	+13	+9	-10
6	14.32	.14	.42	- .50	20	-12	-11	-11
Average	8.46	+1.42	+1.43	+1.80	23	-3	-3	-6
SMSp-W	7.48	+0.69	+0.69	+1.43	19	-7	-5	-5
" Y	10.47	1.32	.81	1.29	16	-8	-7	-10
MSp-W	9.31	.28	- .23	.07	23	-11	-9	-13
" Y	9.21	1.16	+1.53	1.12	19	-11	-11	-14
SLMSp-W	10.07	1.07	.95	.68	11	+1	0	-4
" Y	14.46	.01	.45	.26	28	-12	-10	-16
LMSp-W	16.21	- .39	- .73	- .65	19	-11	-13	-16
SMT-Y	9.45	+ .15	+ .52	+1.64	11	-3	-3	-6
SLMT-Y	12.52	.73	1.22	2.42	22	-10	-11	-13
Average	11.02	+0.56	+0.58	+0.92	19	-8	-8	-11

APPENDIX A.--(Continued)

Grade and position	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	17. YARN SKEIN STRENGTH, 22s				18. YARN SKEIN STRENGTH			
	(Pounds)	Differences			(Pounds)	Differences		
							50s	
GM-2	116.5	-0.7	-4.1	-3.4	41.1	-0.1	-2.6	-1.1
3	120.3	- .3	-8.0	-7.4	41.6	+ .6	-1.6	-2.1
4	142.7	-7.3	-13.5	-9.4	51.0	- .6	-2.8	- .8
5	134.6	-1.7	-5.2	-3.9	49.0	- .3	-2.6	- .6
SM-1	112.7	- .9	-4.5	-7.0	38.8	+ .3	-1.1	-1.3
3	125.1	-1.4	-6.2	-5.8	43.0	1.0	-1.4	-1.5
4	151.9	-5.4	-12.8	-14.9	53.8	.6	-2.8	-3.1
6	120.8	- .5	-9.3	-6.1	41.3	1.1	+ .1	+ .7
M-1	120.8	-2.0	-7.1	-4.4	41.6	.4	-2.3	.6
3	121.9	-3.3	-5.5	-6.2	41.3	.8	+ .1	- .4
4	132.0	-1.6	-8.9	-4.1	45.3	1.8	.2	0
5	91.5	-1.2	-2.4	-2.4	30.2	.5	.2	- .6
SLM-1	120.3	-3.6	-7.7	-4.9	41.4	- .3	-1.5	- .3
LM-1	116.8	-2.6	-3.9	-4.6	42.3	- .9	-1.7	-1.9
4	124.5	-2.9	-5.6	-4.8	44.1	- .6	-1.3	- .5
5	117.6	-2.5	-3.4	-3.5	40.8	+ .3	+ .3	+ .2
GO-4	127.3	+3.9	-8.6	-1.4	45.6	.5	-1.7	.6
3	123.5	-5.5	-8.4	-2.0	44.5	- .5	-1.5	.2
6	106.0	0	-3.0	-2.0	(31.7	+ .4	- .1	+1.0)*
Average	122.5	-2.1	-6.7	-5.2	43.2	+0.3	-1.3	-0.7
							8s	
SMSp-W	90.0	-1.0	-5.0	-2.0	295	+ 1	-12	- 7
" Y	85.0	0	-3.0	-3.0	270	7	- 2	- 1
MSp-W	105.0	-1.0	-5.0	-4.0	349	- 17	-13	- 16
" Y	94.0	-2.0	-3.0	-3.0	312	- 8	- 6	- 4
SLMSp-W	117.4	-1.8	-4.9	-4.0	(40.4	+4.3	0	0)**
" Y	102.0	-3.0	-5.0	-3.0	335	- 7	-13	- 4
LMSp-W	86.0	-3.0	-9.0	-7.0	282	- 9	-23	- 21
SMT-Y	91.0	-1.0	-4.0	-5.0	298	- 11	-23	- 13
SLMT-Y	94.0	-2.0	-7.0	-10.0	307	- 19	-25	- 24
Average	96.0	-1.6	-5.1	-4.6	306	- 8	-15	- 11

* Yarn strength of white grades all for 50s, except this one sample which is 8s.
** Yarn strength of colored grades all for 8s, except this one sample which is 50s.

APPENDIX A.--(Continued)

Grade and position	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%
	19. YARN APPEARANCE, 22s				20. YARN APPEARANCE			
	(Index)	Differences			(Index)	Differences	50s	
GM-2	120	0	0	0	110	0	0	0
3	110	0	0	+10	110	-10	0	-10
4	100	0	+10	10	100	-10	0	0
5	100	0	10	0	100	-10	0	-10
SM-1	100	0	10	10	100	-10	0	0
3	110	0	10	10	110	0	0	0
4	110	-10	0	0	100	0	+10	0
6	110	0	10	0	100	0	0	0
M-1	110	+10	0	0	100	0	0	0
3	110	0	10	0	100	0	0	0
4	100	0	10	10	100	0	0	0
5	100	0	10	10	90	0	0	0
SLM-1	100	0	10	0	100	-10	-10	-10
LM-1	100	0	0	0	90	-10	-10	-10
4	100	0	0	0	90	0	0	0
5	100	0	10	0	100	-10	0	0
GO-4	90	-10	0	0	80	-10	0	-10
3	80	-10	0	0	80	-20	-10	-10
6	90	+10	10	0	(110	-10	-10	-10)*
Average	102	- 1	+ 6	+ 3	50s 98	- 6	- 1	- 3
					8s 110	-10	-10	-10
							8s	
SMSp-W	90	+10	+10	+10	100	+10	+10	+10
" Y	100	0	0	0	110	0	0	0
MSp-W	90	+10	10	10	100	0	10	0
" Y	100	0	10	0	100	10	10	+10
SLMSp-W	100	0	10	0	(100	-10	0	0)**
" Y	90	0	10	0	100	0	0	0
LMSp-W	100	0	0	0	100	0	10	10
SMT-Y	100	0	0	0	110	0	-10	10
SLMT-Y	80	0	-10	+10	90	0	0	10
Average	94	+ 2	+ 4	+ 3	8s 101	+ 3	+ 4	+ 6
					50s 100	-10	0	0

* See Page 29
** See Page 29

APPENDIX A.--(Continued)

Grade and Position	Orig. R_d	Orig. +b	RAW STOCK, R_d and b: 2 years 50° 50% R_d	b	2 years 100° 50% R_d	b	1 year 100° 85% R_d	b	RAW STOCK COLOR INDEX: Orig.	2 years 50° 50%	2 years 100° 50%	1 year 100° 85%
			21. COLOR OF RAW STOCK (R_d, +b, Index)									
			Differences						Index	Differences		
GM-2	80.7	9.2	-0.9	-0.3	-2.8	+2.7	-4.0	+2.1	106	-1	0	-2
3	78.2	9.4	- .1	0	-3.5	3.5	-4.9	2.9	104	0	-1	-4
4	80.8	8.2	- .5	+ .2	-6.6	5.1	-7.4	4.1	105	0	-3	-5
5	79.7	9.8	- .5	- .1	-3.8	2.9	-5.7	2.8	106	-1	-2	-5
SM-1	81.2	7.7	-1.0	+ .3	-3.4	3.4	-5.6	3.6	105	-1	0	-3
3	77.2	9.6	+ .3	0	- .3	1.7	-2.2	2.2	102	0	+2	0
4	79.7	8.7	0	0	-6.0	4.3	-5.0	3.7	105	-1	-2	-3
6	77.5	9.5	+ .6	0	-1.9	2.5	-2.8	2.5	103	-1	0	-1
M-1	77.1	8.1	.1	+ .1	- .7	2.0	-4.1	3.0	102	-1	0	-4
3	76.6	8.9	.3	- .1	- .4	1.5	-3.1	2.6	102	0	0	-4
4	78.9	7.7	- .8	+ .3	-4.3	4.2	-6.9	4.0	103	-1	-1	-6
5	74.8	9.1	+ .5	- .2	- .1	.8	-2.0	1.9	100	0	-2	-2
SLM-1	73.6	7.9	1.2	0	-1.2	1.4	-3.2	2.4	96	+1	0	-4
LM-1	67.8	7.0	-2.1	+ .2	-1.2	1.8	-4.4	2.8	85	-3	-2	-5
4	70.2	6.7	-1.1	.1	-2.4	3.3	-4.7	3.3	89	-2	-1	-6
5	65.8	8.1	+0.4	0	- .7	.7	-2.3	1.7	83	+1	-1	-4
GO-4	57.5	5.7	+2.1	- .1	- .3	1.3	- .1	2.3	72	+2	0	-1
3	53.6	6.7	1.3	- .2	+ .5	1.3	- .8	2.4	68	+1	0	-1
6	55.1	7.4	.1	0	1.3	.5	-1.9	1.0	70	0	0	-4
Average	72.9	8.2	0	0	-2.0	+2.4	-3.8	+2.7	95	0	-1	-3
SMSp-W	73.6	11.4	-0.2	0	-4.9	+2.8	-9.0	+2.1	99	0	-4	-17
" Y	71.0	12.9	+ .3	-0.7	- .1	.8	-7.8	.4	94	+2	+2	-12
MSp-W	72.7	10.4	- .6	+ .1	-4.0	2.8	-8.1	2.4	97	-1	-5	-14
" Y	70.6	12.2	- .3	- .2	-1.8	1.0	-4.1	1.0	95	-2	-3	-9
SLMSp-W	67.7	9.8	-1.2	+ .3	-3.7	2.7	-9.2	2.7	86	-1	-4	-14
" Y	64.9	11.6	+1.1	- .4	- .9	.7	-5.8	.5	82	+2	-1	-10
LMSp-W	63.6	9.7	.3	0	-2.0	1.5	-7.0	2.2	80	0	-3	-10
SMT-Y	68.3	13.8	.9	- .4	-2.0	.9	-6.0	.4	90	+2	-4	-10
SLMT-Y	58.4	14.5	.9	- .1	-3.1	1.4	-10.2	.5	71	+1	-4	-11
Average	67.9	11.8	+0.1	-0.2	-2.5	+1.6	-7.4	+1.4	88	0	-3	-12

APPENDIX A.--(Continued)

Grade and position	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year at 100°/85%	Measurements: Before storage	After storage for 2 years at 50°/50%	After storage for 2 years at 100°/50%	After storage for 1 year 100°/85%
	21a. GRADE FROM COLOR MEASUREMENT				21b. 1960 LOAN PREMIUM & DISCOUNTS (1") FOR GRADES FROM COLOR MEASUREMENTS			
					Pts.	Pts.	Pts.	Pts.
GM-2	GM	SM	GM LtSp	GM LtSp	70	60	-105	-105
3	SM	SM	GM LtSp	GM Sp	60	60	-105	-310
4	SM	SM	GM LtSp	GM Sp	60	60	-105	-310
5	GM	GM	GM LtSp	GM Sp	70	70	-105	-310
SM-1	SM	SM	GM LtSp	GM Sp	60	60	-105	-310
3	SM	SM	GM LtSp	GM Sp	60	60	-105	-310
4	SM	SM	GM Sp	GM Sp	60	60	-310	-310
6	SM	SM	GM Sp	GM Sp	60	60	-310	-310
M-1	M	M	SM LtSp	SM Sp	0	0	-125	-330
3	M	M	SM LtSp	SM Sp	0	0	-125	-330
4	M	M	GM LtSp	SM Sp	0	0	-105	-330
5	M	M	M LtSp	SM Sp	0	0	-285	-330
SLM-1	SLM	SLM	SLM LtSp	SLM Sp	-280	-280	-525	-800
LM-1	LM	LM	LM LtSp	LM Sp	-525	-525	-785	-1045
4	LM	LM	SLM Sp	SLM Sp	-525	-525	-800	-800
5	LM	LM	LM	LM Sp	-525	-525	-525	-1045
GO-4	GO	GO	GO	GO	-1010	-1010	-1010	-1010
3	GO	GO	GO	BG	-1010	-1010	-1010	-1200*
6	GO	GO	GO	BG	-1010	-1010	-1010	-1200*
Av.					-283	-283	-398	-563
Diff.					Orig.	0	-115	-280
SM Sp-W	SM Sp	SM Sp	GM Tg	M Tg	-330	-330	-835	-1020
" Y	SM Sp	SM Sp	GM Tg	M Tg	-330	-330	-835	-1020
M Sp-W	M Sp	M Sp	SM Tg	M Tg	-560	-560	-860	-1020
" Y	M Sp	M Sp	SM Tg	M Tg	-560	-560	-860	-1020
SLM Sp-W	SLM Sp	SLM Sp	SLM Tg	LM Tg	-800	-800	-1210	-1380
" Y	SLM Sp	SLM Sp	SLM Tg	LM Tg	-800	-800	-1210	-1380
LM Sp-W	LM Sp	LM Sp	LM Sp	LM Tg	-1045	-1045	-1045	-1380
SMT-Y	SM Tg	SM Tg	SM Tg	M Tg	-860	-860	-860	-1020
SLMT-Y	SLM Tg	SLM Tg	M Ys	BG Ys	-1210	-1210	-1105	-1500*
Av.					-722	-722	-980	-1193
Diff.					Orig.	0	-258	-471

* Estimated

APPENDIX A.--(Continued)

Grade and Position	Orig.		GREY YARN, R_d and b						GREY YARN COLOR INDEX			
			2 years				1 year		Orig.	2 years		1 year
			50°/50%		100°/50%		100°/85%			50°/50%	100°/50%	100°/85%
			22. GREY YARN, (R_d, +b, Index)									
			Differences						Index	Differences		
			R_d	b	R_d	b	R_d	b				
GM-2	74.2	12.0	+0.3	+0.1	-2.2	+2.8	-2.7	+2.2	106	0	+8	+4
3	72.8	12.5	- .3	- .3	-5.1	3.2	-4.8	2.5	106	-2	4	2
4	74.4	11.7	+ .4	- .1	-7.0	4.6	-4.8	3.9	105	+1	10	6
5	72.6	13.0	- .3	- .1	-3.4	3.6	-5.0	2.4	107	-1	10	2
SM-1	73.8	11.0	+1.7	0	-2.4	3.0	-2.6	3.1	101	+3	7	8
3	73.1	12.7	- .3	+ .1	-2.9	1.7	-3.3	2.3	106	0	2	4
4	74.0	11.8	+ .4	- .1	-6.1	4.6	-4.3	3.7	105	0	11	6
6	73.2	12.6	- .1	- .5	-3.4	3.0	-2.4	2.8	106	-1	8	6
M-1	71.4	11.2	+ .5	- .4	-1.9	2.2	-3.9	2.2	99	0	5	1
3	72.0	12.3	.5	- .2	-1.4	1.3	-3.1	2.2	104	0	2	3
4	73.5	11.0	- .1	- .2	-5.9	3.7	-5.5	3.6	102	-1	3	4
5	70.8	11.7	- .2	- .1	- .4	1.2	- .4	1.3	100	-1	3	4
SLM-1	70.4	11.2	+ .6	- .4	-1.1	1.2	-2.8	1.4	97	0	2	-1
LM-1	63.2	10.6	+ .8	- .2	-1.0	1.7	-1.5	3.0	81	+1	3	+5
4	67.5	10.6	+ .7	- .3	-4.2	3.2	-6.3	4.2	89	1	2	1
5	64.8	11.6	-2.0	- .1	-2.5	1.0	-4.6	1.4	87	-4	-2	-5
GO-4	62.2	8.8	-1.1	- .1	-1.5	1.2	-2.0	2.6	76	-1	0	+3
3	54.5	9.2	-1.5	+ .3	-1.9	2.0	- .9	2.8	70	-1	-1	0
6	53.8	10.0	-0.9	- .1	+ .8	1.0	-1.4	1.3	70	-1	+1	-1
Average	69.1	11.3	-0.1	-0.1	-2.8	+2.4	-3.3	+2.6	96	0	+4	+3
SMSp-W	66.0	14.6	+0.6	+0.1	-5.6	3.1	-9.1	+1.7	102	+2	+2	-18
" Y	64.0	16.2	1.4	.2	-2.4	1.3	-6.8	0	105	4	0	-21
MSp-W	64.1	13.5	1.7	.8	-4.3	3.1	-4.9	2.5	92	8	+3	-3
" Y	64.2	15.2	.6	.8	- .4	1.2	-2.5	1.1	100	6	6	0
SLMSp-W	62.8	13.5	- .2	.1	-5.4	2.1	-9.8	1.4	89	-1	-5	-16
" Y	59.7	14.8	+1.2	- .6	-2.1	.8	-6.6	0	86	0	-2	-12
LMSp-W	58.4	12.3	- .2	+ .2	-3.2	1.9	-6.6	1.7	77	0	-1	-7
SMT-Y	61.4	16.6	- .4	.1	-3.2	1.4	-4.8	.2	100	0	-2	-14
SLMT-Y	50.4	16.0	-1.1	.5	-5.0	1.2	-10.0	- .1	71	-2	-11	-21
Average	60.6	14.7	+0.4	+0.2	-3.5	+1.8	-6.2	+0.9	91	+2	-1	-12

APPENDIX A.--(Continued)

Grade and Position	Orig.		BLEACHED 22's YARN, R_d and b: 2 years: 50°/50%		2 years: 100°/50%		1 year: 100°/85%		BLEACHED YARN COLOR INDEX: Orig.	2 years: 50°/50%	2 years: 100°/50%	1 year: 100°/85%
			23. COLOR OF BLEACHED YARN (R_d, +b, Index)									
			Differences						Index	Differences		
	R_d	+b	R_d	b	R_d	b	R_d	b				
GM-2	85.2	3.0	+0.7	+0.1	+0.8	+0.7	-0.3	+1.1	106	+1	-1	-6
3	85.3	3.2	- .8	- .4	.2	.6	-1.3	1.5	105	0	-2	-9
4	84.9	2.8	- .4	- .1	.6	.8	- .5	1.3	106	1	-2	-7
5	85.4	3.2	0	- .2	.4	.4	-1.2	1.2	105	1	-1	-7
SM-1	85.2	2.6	- .1	- .1	1.3	1.0	-1.1	1.5	107	0	-1	-8
3	85.2	3.2	+ .3	0	.7	.7	-1.2	1.7	105	0	-1	-10
4	84.4	2.6	- .4	0	1.3	1.2	- .6	1.3	105	-1	-1	-6
6	85.8	2.9	-1.6	- .3	- .6	.5	-2.2	1.4	107	-2	-3	-10
M-1	83.3	3.4	+ .9	- .1	+ .7	.5	- .2	1.2	99	+3	0	-5
3	85.2	3.5	- .5	+ .1	.4	.5	-1.1	1.2	104	-2	-2	-8
4	84.9	2.8	+ .2	0	1.1	.8	-1.4	1.3	106	0	-1	-9
5	84.8	2.6	.3	- .1	1.1	.4	-1.2	.8	106	+1	+1	-6
SLM-1	83.4	3.0	.9	- .4	.5	.2	0	.7	101	4	-2	-2
LM-1	79.1	4.2	.8	- .2	.8	.1	+ .1	1.1	86	3	+2	-4
4	83.4	3.3	.5	- .2	- .1	.7	- .9	1.8	100	2	-3	-9
5	82.8	3.4	-2.2	- .5	- .3	.2	-1.3	.5	99	-8	-2	-6
GO-4	79.4	3.8	- .5	0	- .7	.6	+ .5	.9	89	-1	-4	-2
3	78.8	4.3	+ .7	+ .1	- .1	.5	.2	.6	86	0	-3	-3
6	80.0	6.0	- .1	.4	- .3	.6	- .8	- .1	81	-1	-3	-1
Average	83.5	3.4	-0.1	-0.2	+0.6	+0.6	-0.7	+1.1	100	0	-2	-6
SMSp-W	83.4	3.4	+0.9	+0.8	+0.8	+1.7	+0.8	+2.7	99	0	-4	-8
" Y	83.4	4.1	- .5	.1	.2	.3	- .7	1.8	97	-2	-1	-7
MSp-W	80.8	3.4	+2.3	.9	1.5	1.4	+1.9	2.1	95	+1	-3	-5
" Y	81.8	3.8	.4	.4	.1	.6	- .2	1.3	95	-1	-3	-6
SLMSp-W	84.4	4.0	1.0	- .2	.8	.6	-1.2	1.3	99	+4	0	-7
" Y	78.8	4.5	- .1	+ .3	-1.2	.7	0	1.6	85	-2	-6	-7
LMSp-W	73.2	3.6	+ .1	.2	+ .6	.9	- .2	1.7	77	-2	-4	-9
SMT-Y	83.2	4.4	- .5	.2	-1.7	.7	-1.7	2.9	95	-2	-6	-15
SLMT-Y	75.6	5.2	+1.5	.3	+1.9	1.3	+ .4	3.0	74	+2	-1	-11
Average	80.5	4.0	+0.6	+0.3	+0.3	+0.9	-0.1	+2.0	91	0	-3	-8

APPENDIX A.--(Continued)

24. COLOR OF DYED YARN (R_d, -b, Index)

Grade and Position	Orig.		BLEACHED AND DYED YARNS, R_d & -b: 2 years: $50^o/50\%$ (Differences)		2 years: $100^o/50\%$		1 year: $100^o/85\%$		BLEACHED & DYED COLOR INDEX: Orig. (Index)	2 years: $50^o/50\%$ (Differences)	2 years: $100^o/50\%$	1 year: $100^o/85\%$
	R_d	-b	R_d	b	R_d	b	R_d	b				
GM-2	26.0	26.8	-1.3	+0.9	0	+0.3	+2.4	+0.2	110	+5	0	-5
3	28.2	26.0	-2.1	.6	+0.1	- .3	1.5	- .3	102	6	-2	-5
4	26.7	26.6	-1.2	.7	.6	- .3	3.1	-1.6	107	5	-3	-13
5	26.6	26.2	-1.5	.7	.1	+ .3	1.9	- .5	106	5	+1	-6
SM-1	27.6	26.2	- .3	.3	- .7	.3	2.3	- .8	104	2	2	-8
3	26.4	26.1	- .3	.6	+ .7	.2	3.5	+ .1	107	2	-2	-8
4	25.3	27.3	-1.8	.9	1.7	- .6	4.3	-3.1	112	8	-5	-21
6	27.6	25.9	-2.1	1.5	0	- .4	1.8	- .5	103	10	+1	-6
M-1	27.0	26.0	-2.2	1.3	.7	+ .3	1.9	0	104	10	2	-4
3	27.8	25.6	- .3	0	.5	.3	2.5	-1.0	101	-1	2	-9
4	27.8	26.0	- .1	.3	.7	- .5	2.2	- .8	102	+1	-3	-7
5	26.6	27.2	- .7	.5	.1	+ .1	2.1	- .2	109	4	+1	-5
SLM-1	26.4	26.4	- .9	.8	1.0	- .3	2.5	- .4	107	4	-3	-7
LM-1	28.8	23.7	-1.7	1.2	.3	+ .2	1.9	- .5	91	8	0	-6
4	28.4	24.8	-2.2	1.3	- .3	- .3	2.3	- .2	97	9	-1	-6
5	30.6	24.3	-1.5	.6	+ .7	- .2	.9	- .9	90	5	-2	-5
GO-4	29.8	23.4	- .3	0	- .1	- .3	2.4	-1.2	88	1	-1	-10
3	29.2	23.0	- .5	.7	+ .5	+ .1	1.3	+1.4	88	4	-1	+6
6	32.1	21.8	- .3	- .5	- .9	.2	.2	0	77	-2	+3	0
Average	30.0	25.4	-1.1	+0.7	+0.3	0	+2.2	-0.5	100	+5	-1	-7
SMSp-W	25.2	27.0	+0.3	+0.2	+2.1	-1.0	+3.1	-1.8	112	-1	-9	-14
" Y	29.8	24.6	- .4	.4	1.0	- .7	2.7	-1.2	93	+2	-5	-10
MSp-W	25.4	25.8	+ .2	1.1	1.6	- .3	3.9	-2.4	106	5	-4	-18
" Y	28.0	26.0	.6	- .3	1.5	-1.0	2.2	-2.4	102	-2	-7	-14
SLMSp-W	25.0	26.6	-2.1	+1.2	.9	- .7	1.5	-1.4	110	+10	-4	-9
" Y	28.9	23.5	- .3	.2	1.0	+1.4	2.0	-1.6	90	2	-10	-10
LMSp-W	30.4	21.8	-1.4	.7	.8	- .5	1.5	+1.5	81	5	-5	+2
SMT-Y	30.2	24.6	- .8	- .2	- .2	- .9	1.1	-2.2	92	1	-3	-11
SLMT-Y	27.8	23.8	-1.1	+ .4	+ .8	+1.2	3.1	-2.6	94	3	-7	-17
Average	27.9	24.9	-0.6	+0.4	+1.1	-0.3	+2.3	-1.6	98	+3	-6	-9

APPENDIX B.--Cotton from 10 American Egyptian grade standards bales stored under controlled conditions of temperature and humidity, measurement before storage and differences after storage for 33 classification, fiber, and spinning tests

Ident. Lot No.	AE Grade	Measurements: Orig.	After storage for 2 years: 50°/50%	After storage for 2 years: 100°/50%	After storage for 1 year: 100°/85%	Orig.	After storage for 2 years: 50°/50%	After storage for 2 years: 100°/50%	After storage for 1 year: 100°/85%
			1. CLASSERS' GRADE(Index)				2. CLASSERS' STAPLE (32nd")		
		Index	Differences			Inches	Differences		
1	1	95	-2	-6	-15	46	0	0	0
2	1	95	-2	-6	-9	46	0	0	0
3	3	89	-3	-6	-15	46	-2	-2	-4
4	3	89	0	-3	-6	46	0	-2	-2
5	5	83	0	-6	-18	46	-2	-2	-4
6	5	83	-3	-12	-18	46	-2	-4	-4
7	7	77	-3	-12	-12	44	-2	-2	-2
8	7	77	-3	-6	-12	44	-2	0	0
9	9	71	0	0	-6	46	-2	-4	-2
10	9	71	0	-6	-6	44	-2	-2	0
Average		83	-2	-6	-12	45	-1	-2	-2
			3. LENGTH ARRAY - UHL				4. LENGTH ARRAY - COEF. OF VARIATION		
		Inches	Differences			Percent	Differences		
1		1.39	0	-0.01	0	23	+3	+2	+2
2		1.41	+0.02	- .04	0	27	0	1	0
3		1.38	.01	- .01	+0.01	29	0	1	2
4		1.42	.01	- .03	0	28	0	0	-1
5		1.33	.03	+ .01	.03	32	0	3	0
6		1.41	- .07	.01	.01	28	0	-1	+1
7		1.39	+ .03	.02	.02	26	2	+4	4
8		1.42	- .03	- .03	0	27	1	0	1
9		1.42	0	+ .04	0	30	0	1	-2
10		1.49	- .01	- .03	.04	35	-2	-1	-5
Average		1.41	0	-0.01	+0.01	29	0	+1	0
			5. FIBROGRAPH, UHM LENGTH				6. FIBROGRAPH, UNIFORMITY RATIO		
		Inches	Differences			Index	Differences		
1		1.28	-0.02	- .02	+0.02	84	-1	-1	-3
2		1.30	0	- .03	0	84	-2	-1	-6
3		1.26	+ .01	0	.02	83	-1	-2	-5
4		1.31	- .03	- .03	0	84	-2	-1	-6
5		1.26	- .04	- .02	- .01	81	-1	-2	-7
6		1.26	0	0	+ .02	83	-1	-2	-6
7		1.25	+ .01	+ .03	+ .04	82	-1	0	-5
8		1.30	- .03	- .02	- .02	85	-4	-4	-8
9		1.32	- .02	- .01	0	83	-1	-2	-6
10		1.37	- .02	- .02	- .02	79	0	0	-6
Average		1.29	-0.01	-0.01	+0.01	83	-1	-2	-6

APPENDIX B.--(Continued)

Ident. Lot No.	AE Grade	Orig.	After storage for 2 years 50°/50%	After storage for 2 years 100°/50%	After storage for 1 year 100°/85%	Orig.	After storage for 2 years 50°/50%	After storage for 2 years 100°/50%	After storage for 1 year 100°/85%
			2a. CLASSER'S GRADE				2b. 1960 LOAN PREMIUMS & DISCOUNTS (1-7/16")FOR GRADES FROM COLOR MEAS-UREMENTS		
						¢	¢	¢	¢
1	1	1	2	3	6	2.20	1.55	0	-8.95
2	1	1	2	3	4	2.20	1.55	0	-2.30
3	3	3	4	5	8	0	-2.30	-5.30	-15.75
4	3	3	3	4	5	0	0	-2.30	-5.30
5	5	5	5	7	10	-5.30	-5.30	-12.05	-22.85*
6	5	5	6	9	10	-5.30	-8.95	-19.30	-22.85*
7	7	7	8	10	10	-12.05	-15.75	-22.85*	-22.85*
8	7	7	8	9	10	-12.05	-15.75	-19.30	-22.85*
9	9	9	9	9	10	-19.30	-19.30	-19.30	-22.85*
10	9	9	9	10	10	-19.30	-19.30	-22.85*	-22.85*
Av.		5.0				-6.89	-8.36	-12.33	-16.94
Diff.						Orig	-1.47	-5.44	-10.05
			3a. MEAN LENGTH, ARRAY				5a. MEAN LENGTH, FIBROGRAPH		
1		1.21	- .03	- .04	- .03	1.08	-0.03	- .04	-0.03
2		1.18	+ .02	- .04	0	1.09	- .02	- .04	- .07
3		1.15	0	- .01	- .01	1.04	0	- .02	- .04
4		1.18	+ .01	- .02	0	1.10	- .05	- .04	- .08
5		1.07	+ .03	- .01	+ .03	1.02	- .04	- .04	- .10
6		1.18	- .03	+ .02	0	1.05	- .02	- .03	- .07
7		1.18	+ .01	- .01	- .02	1.02	0	+1.03	- .03
8		1.20	- .03	- .03	- .01	1.11	- .08	- .07	- .12
9		1.16	0	+ .03	+ .02	1.10	- .04	- .04	- .08
10		1.18	+ .08	- .02	- .08	1.08	- .02	- .01	- .10
Average		1.17	0	-0.01	0	1.07	- .03	- .03	- .07

*Below Grade given price discount equal to one grade below quotation for grade 9.

APPENDIX B.--(Continued)

Ident. Lot No.	AE Grade	Measurements: Orig.	After storage for 2 years: 50°/50%	After storage for 2 years: 100°/50%	After storage for 1 year: 100°/85%	Orig.	After storage for 2 years: 50°/50%	After storage for 2 years: 100°/50%	After storage for 1 year: 100°/85%
			7. MICRONAIRE (Reading)				8. CAUSTICAIRE-FINENESS		
		Units	Differences			ug/in	Differences		
1		3.8	0	+0.2	0	3.4	+0.2	0	+0.1
2		3.5	+0.1	2	+0.3	3.2	0	0	0
3		3.4	0	0	0	3.1	0	-0.1	- .1
4		3.8	.1	0	0	3.5	0	0	- .1
5		2.9	.1	0	+ .1	2.6	.2	+ .1	+ .1
6		3.2	0	0	.2	2.8	.1	0	.2
7		3.2	0	0	.1	3.1	0	- .2	- .1
8		3.6	.1	.1	0	3.3	.1	0	0
9		3.4	.4	.2	.2	3.1	.2	+ .4	+ .3
10		3.4	.2	.2	.1	3.5	0	0	0
Average		3.4	+0.1	+0.1	+0.1	3.2	+0.1	0	0
			9. CAUSTICAIRE-MATURITY				10. PRESSLEY STRENGTH 0 Gage		
		Index	Differences			Index	Differences		
1		79	-1	+3	0	95	+7	+5	+3
2		76	+3	4	+4	100	1	-3	-4
3		75	3	2	1	93	11	+6	+7
4		78	2	0	2	92	8	3	6
5		69	1	-1	1	97	7	2	6
6		73	1	+2	3	99	4	1	-1
7		71	2	2	4	100	2	0	-3
8		76	2	2	2	96	1	1	+2
9		76	4	-1	1	100	3	0	4
10		72	3	+4	3	100	4	-1	4
Average		75	+2	+2	+2	97	+5	+1	+2
			11. PRESSLEY STRENGTH 1/8" Gage				12. SHIRLEY ANALYZER NON-LINT		
		Index	Differences			Percent	Differences		
1		154	0	+2	+6	1.47	-0.19	+0.11	+0.37
2		155	-3	-2	0	2.35	- .46	- .66	- .34
3		161	+6	-3	-2	3.43	+ .83	+ .64	+ .77
4		150	-2	-2	+6	3.66	- .54	.10	- .56
5		160	-6	-8	-3	6.92	+ .56	- .09	+ .83
6		158	-4	0	+1	8.90	.17	+ .75	.67
7		160	-6	-6	-7	11.11	1.10	+1.66	-1.93
8		144	-7	+5	+7	6.77	1.00	1.86	+ .78
9		172	-20	-20	-3	10.51	-1.67	- .93	.09
10		154	-7	-8	0	12.53	+1.63	+1.67	.95
Average		157	-5	-4	+1	6.77	+0.24	+0.51	+0.16

APPENDIX B.--(Continued)

Ident Lot No.	AE Grade	Measurements							
		Orig.	After storage for			Orig.	After storafe for		
			2 years		1 year		2 years		1 year
			$50^{o}/50\%$	$100^{o}/50\%$	$100^{o}/85\%$		$50^{o}/50\%$	$100^{o}/50\%$	$100^{o}/85\%$
			13. SUGAR CONTENT				14. ACID-ALKALINE VALUE (pH)		
		Percent	Differences			Units	Differences		
1		0.1	+0.1	0	-0.1	6.4	-0.2	-0.5	+0.1
2		.2	0	-0.1	- .1	6.2	- .3	- .3	.3
3		.3	.5	+ .3	- .2	6.0	+ .1	- .4	.3
4		.1	.2	.1	0	6.4	- .3	- .6	- .3
5		.6	.2	0	- .4	5.8	+ .1	- .5	+ .5
6		.7	.1	- .1	- .6	5.8	.2	- .3	.6
7		.6	0	0	- .5	6.0	0	- .4	.4
8		.4	.1	- .2	- .4	6.0	- .1	- .4	1.0
9		.2	- .1	0	- .1	6.9	.4	-1.0	- .2
10		.6	0	0	- .5	6.2	.3	- .5	+ .4
Average		0.4	+0.1	0	-0.3	6.2	-0.1	-0.5	+0.3
			15. PICKER WASTE				16. CARD WASTE		
		Percent	Differences			Percent	Differences		
1		1.05	+0.28	-0.19	+0.24	7.18	-0.27	-0.81	-0.87
2		1.29	- .19	- .15	.53	7.33	+ .20	- .10	- .64
3		2.14	- .34	+ .38	.29	9.04	- .49	- .87	- .74
4		2.12	+ .29	.01	- .12	7.50	+ .36	+ .23	- .22
5		3.91	- .03	- .14	- .05	11.41	- .78	- .73	-1.21
6		4.43	+ .82	+ .02	+3.03	11.31	+ .31	+ .30	+ .15
7		6.21	.70	.23	.08	12.68	.95	.74	.01
8		3.86	.43	.58	.33	11.86	.37	.10	- .13
9		5.14	.10	- .10	.34	10.89	.31	-1.08	+ .16
10		9.56	- .38	- .22	- .25	12.69	- .43	-1.04	- .52
Average		3.98	+0.17	+0.04	+0.44	10.19	+0.05	-0.33	-0.40
			17. PICKER & CARD WASTE				18. COMBER WASTE		
		Percent	Differences			Percent	Differences		
1		8.15	0	-0.97	-0.63	10.80	+1.67	+1.79	+2.88
2		8.53	+ .02	- .24	- .14	13.32	.55	.41	2.10
3		10.99	- .79	- .51	- .46	13.43	1.29	.72	2.31
4		9.46	+ .62	+ .24	- .33	12.53	1.22	1.22	3.37
5		14.87	- .77	- .82	-1.20	14.36	1.18	1.04	2.99
6		15.24	+1.02	+ .30	+2.83	13.59	1.57	.73	2.16
7		18.10	1.50	.90	.08	13.65	.99	1.39	2.69
8		15.26	.74	.61	.17	13.58	1.06	1.54	2.92
9		15.47	.38	-1.11	.45	13.35	1.40	.94	4.79
10		21.12	- .73	-1.14	- .69	14.07	.65	.94	2.84
Average		13.72	+0.34	-0.27	+0.01	12.27	+1.16	+1.07	+3.90

APPENDIX B.--(Continued)

Ident Lot No.	AE Grade	Orig.	After storage for: 2 years 50°/50%	2 years 100°/50%	1 year 100°/85%	Orig.	After storage for: 2 years 50°/50%	2 years 100°/50%	1 year 100°/85%
			19. PICKER, COMB, AND CARD WASTE				20. NEPS IN CARD WEB		
		Percent	Differences			No.	Differences		
1		18.07	+1.53	+0.80	+2.10	6	0	+2	-1
2		20.71	.52	.17	1.81	9	-1	-2	+3
3		22.94	.48	.21	1.67	8	-1	-3	-1
4		20.80	1.64	1.32	2.78	5	-1	+1	+3
5		27.09	.36	.20	1.56	7	0	3	2
6		26.76	2.19	.87	4.21	10	-3	-3	-2
7		29.28	2.09	1.90	2.27	7	0	+1	+2
8		26.77	1.53	1.82	2.61	14	0	-1	-1
9		26.75	1.51	- .15	4.42	8	-1	-4	-1
10		32.22	- .11	- .23	1.67	8	-3	-5	-4
Average		25.14	+1.17	+0.69	+2.51	8	-1	-1	0
			21. YARN SKEIN STRENGTH, 50s (COMBED)				22. YARN SKEIN STRENGTH, 80s (COMBED)		
		Lbs.	Differences			Lbs.	Differences		
1		72.0	+0.6	+1.0	+1.5	40.6	-0.6	-2.0	-0.6
2		71.9	2.6	.4	.8	40.7	- .7	-2.9	- .1
3		74.5	1.0	7	- .6	43.0	- .4	-1.7	-1.6
4		70.5	.4	-1.0	-1.3	39.5	- .7	-1.8	-1.2
5		74.5	1.7	-2.4	-2.1	42.2	- .4	-2.2	- .1
6		75.0	-1.3	-1.6	-2.0	41.5	+1.0	-1.2	- .1
7		72.9	-1.4	-2.0	- .8	41.4	-1.0	-2.4	- .7
8		70.6	- .2	-1.0	-2.5	39.7	-1.0	-1.8	- .1
9		73.9	- .5	-1.1	- .4	41.5	+ .1	- .7	- .6
10		66.6	+1.4	-1.7	- .3	35.9	.9	- .5	+ .5
Average		72.2	+0.4	-0.8	-0.8	40.6	-0.3	-1.7	-0.5
			23. YARN APPEARANCE, 50s (COMBED)				24. YARN APPEARANCE, 80s (COMBED)		
		Index	Differences			Index	Differences		
1		120	0	+10	+10	110	+10	+10	+10
2		120	+10	10	0	110	10	0	10
3		110	10	10	+10	110	-10	0	0
4		130	0	0	-10	120	0	0	0
5		110	0	0	0	100	0	0	0
6		110	0	0	+10	100	0	0	0
7		110	0	0	10	100	0	0	0
8		100	0	+10	10	100	0	0	0
9		120	-10	0	0	110	0	-10	0
10		110	+10	10	10	110	0	0	0
Average		114	+2	+5	+5	107	+1	0	+2

APPENDIX B.--(Continued)

Ident. Lot No.	AE Grade	Measurements											
		Orig.		After storage for						Orig.	After storage for		
				2 years				1 year			2 years		1 year
				50°/50%		100°/50%		100°/85%			50°/50%	100°/50%	100°/85%
		25. COLOR OF RAWSTOCK, R_d & +b, INDEX											
		Index		Differences						Index	Differences		
		R_d	+b	R_d	b	R_d	b	R_d	b				
1	1	70.0	11.6	-1.0	+0.3	-2.5	+1.4	-4.1	+1.8	92	+1	-3	-7
2	1	73.0	11.4	-2.0	0	-3.5	1.3	-4.5	+1.2	96	-3	-7	-6
3	3	68.1	11.8	-2.1	.6	-3.8	2.5	-7.5	1.9	90	-4	-7	-15
4	3	70.7	10.9	-2.3	.4	-3.3	1.4	-4.0	1.6	94	-5	-8	-8
5	5	67.0	12.0	-2.7	.4	-6.0	2.3	-8.5	1.6	87	-4	-10	-15
6	5	66.2	11.7	-1.7	.2	-5.2	2.0	-7.2	1.5	83	-3	-12	-11
7	7	62.2	11.6	-0.2	0	-3.7	1.6	-6.6	2.1	78	-4	-13	-10
8	7	66.0	10.9	-3.0	.7	-3.7	1.8	-10.7	2.2	84	-10	-13	-16
9	9	59.8	10.0	-1.2	.4	-0.3	0.9	-2.4	1.7	74	-3	-3	-3
10	9	62.3	11.4	-3.5	.1	-9.3	1.3	-8.8	0.7	75	-4	-10	-9
Average		66.5	11.3	-2.0	+0.3	-4.1	+1.6	-6.4	+1.6	85	-4	-9	-10
		26. COLOR OF GREY YARN, R_d & +b, INDEX											
		Index		Differences						Index	Differences		
		R_d	+b	R_d	b	R_d	b	R_d	b				
1		63.8	14.6	-1.2	-0.2	-2.7	+1.0	-5.4	+1.2	97	-5	-3	-11
2		65.4	14.4	- .6	+ .8	-2.2	1.6	-4.6	1.2	100	+2	+2	-7
3		61.5	15.4	-1.3	.2	-5.9	1.5	-7.7	1.8	94	-4	-10	-16
4		64.6	14.4	-1.4	- .4	-2.2	1.6	-3.3	1.2	98	-6	+2	-4
5		59.4	15.9	-1.6	+ .2	-6.2	1.8	-8.3	1.1	90	-4	-9	-16
6		59.8	15.8	- .3	- .2	-5.0	1.4	-7.2	.7	91	-3	-9	-15
7		59.6	15.5	- .6	+ .1	-4.1	1.6	-5.8	.9	88	-1	-4	-10
8		63.1	15.4	- .1	- .3	-3.7	.8	-6.3	.9	99	-2	-8	-16
9		59.8	14.4	-1.6	- .2	-2.1	.7	-4.8	1.2	85	-3	-3	-7
10		61.6	15.0	-1.2	- .2	-4.4	1.7	-9.5	1.3	92	-4	-5	-19
Average		61.9	15.1	-1.0	0	-3.8	+1.4	-6.3	+1.2	93	-3	-5	-12
		27. COLOR OF MERCERIZED YARN, R_d & +b											
		Index		Differences									
		R_d	+b	R_d	b	R_d	b	R_d	b				
1		51.7	13.4	-1.1	+1.7	-1.5	+2.0	+1.7	+1.4				
2		54.6	15.0	-3.0	- .8	-2.8	0	-1.3	0				
3		45.0	13.8	- .8	+ .7	-1.2	1.1	+ .8	1.0				
4		57.3	13.6	-5.4	.6	-5.5	.8	-4.1	.7				
5		43.4	14.9	-2.1	- .7	-3.0	.3	-2.6	1.4				
6		51.0	14.4	-8.4	+ .2	-10.0	1.3	-8.8	1.2				
7		43.6	14.2	- .2	1.1	-1.2	.8	-1.0	2.0				
8		55.4	13.8	-5.3	1.4	-7.4	1.8	-5.6	.6				
9		52.8	13.0	-6.0	1.0	-6.6	1.2	-3.2	.8				
10		54.8	14.2	-8.0	1.1	-9.7	.8	-7.2	.6				
Average		51.0	14.0	-4.0	+0.6	-4.9	+1.0	-3.1	+1.0				

APPENDIX B.--(Continued)

Ident Lot No.	AE Grade	Orig.	After storage for 2 years 50°/50%	100°/50%	1 year 100°/85%	Orig.	After storage for 2 years 50°/50%	100°/50%	1 year 100°/85%
			25a. GRADE FROM COLOR MEASUREMENTS				25b. 1960 LOAN PREMIUMS & DISCOUNTS (1-7/16")FOR GRADES FROM COLOR MEASUREMENTS		
						¢	¢	¢	¢
1	1	1	2	3	4	2.20	1.55	0	-2.30
2	1	1	1	1	2	2.20	2.20	2.20	1.55
3	3	2	2	4	8	1.55	1.55	-2.30	-15.75
4	3	2	2	3	4	1.55	1.55	0	-2.30
5	5	4	4	7	9	-2.30	-2.30	-12.07	-19.30
6	5	5	5	8	9	-5.30	-5.30	-15.75	-19.30
7	7	7	7	9	10	-12.05	-12.05	-19.30	-22.85*
8	7	5	6	7	10	-5.30	-8.95	-12.05	-22.85*
9	9	8	9	8	9	-15.75	-19.30	-15.75	-19.30
10	9	8	9	10	10	-15.75	-19.30	-22.85*	-22.85*
Av.						-4.90	-6.04	-9.79	-14.53
Diff.						Orig	-1.14	-4.89	-9.63

* Below Grade given price discount equal to one grade below quotation for grade 9.

APPENDIX B.--(Continued)

Ident. Lot No.	AE Grade	Orig. R_d	Orig. +b	After storage for 2 years 50°/50% R_d	b	100°/50% R_d	b	1 year 100°/85% R_d	b	Orig.	After storage for 2 years 50°/50%	100°/50%	1 year 100°/85%
		28. COLOR OF BLEACHED YARN, R_d & +b, INDEX											
		Index		Differences						Index	Differences		
		R_d	+b	R_d	b	R_d	b	R_d	b				
1		83.1	4.4	-1.2	+0.9	-0.3	+0.2	-0.1	+0.8	95	-6	-1	-4
2		83.0	4.3	+1.3	.2	+1.0	- .2	+ .5	.6	95	+2	+3	-1
3		82.0	4.8	- .7	1.6	.5	+ .8	0	1.7	91	-8	-2	-7
4		81.4	4.4	+ .5	.7	1.9	1.4	1.2	.7	91	-1	-1	0
5		81.2	5.2	1.1	1.2	.7	0	.2	1.7	87	-2	+2	-6
6		80.9	5.2	2.2	- .5	.8	1.0	- .5	1.5	87	+7	-2	-7
7		81.4	5.2	.6	- .6	-1.3	- .4	+ .2	1.3	88	+4	-1	-5
8		81.2	5.2	1.1	+1.1	+2.3	- .9	.4	.8	87	-1	+9	+1
9		79.8	4.7	1.9	.7	4.5	- .3	.2	.8	87	+1	+12	-3
10		80.4	5.2	3.1	.4	1.9	- .8	.6	1.3	86	+5	+7	-4
Average		81.4	4.9	+1.0	+0.6	+1.2	+0.1	+0.4	+1.1	89	0	+3	-3
		29. COLOR OF DYED YARN, R_d & -b, INDEX											
		Index		Differences						Index	Differences		
		R_d	-b	R_d	b	R_d	b	R_d	b				
1		25.5	-26.7	+1.1	-0.6	+2.5	-1.5	+4.4	-2.2	109	-4	+1	-17
2		27.4	-25.8	.3	- .4	1.1	- .9	2.3	-1.1	102	-2	-5	-11
3		25.6	-25.6	1.3	- .5	1.0	- .3	2.9	-1.8	105	-5	-3	-13
4		27.4	-25.1	.4	+ .8	.3	+ .2	3.7	-1.5	99	+3	0	-13
5		26.2	-25.2	1.7	- .9	1.7	-1.5	3.7	-2.7	102	-7	-9	-18
6		26.4	-24.8	.5	+ .1	1.7	-1.3	3.7	-2.0	100	0	-8	-15
7		25.8	-25.6	.5	- .7	2.1	-1.8	5.1	-3.2	105	-4	-11	-23
8		28.4	-24.9	- .7	0	1.3	- .8	2.7	-1.4	97	+1	-6	-11
9		27.8	-24.4	- .4	+ .6	- .5	+ .7	2.2	-1.2	96	3	+4	-9
10		27.8	-24.8	+ .7	0	1.2	-1.3	4.3	-3.0	97	0	-7	-20
Average		26.8	-25.3	+0.5	-0.2	+1.2	-0.8	+3.5	-2.0	101	-2	-6	-15

Ident. Lot No.	AE Grade	30. LUSTER OF GREY YARN, 50s Index	Differences 2 years 50°/50%	100°/50%	1 year 100°/85%	31. LUSTER OF MERCERIZED YARN, 50s Index	Differences 2 years 50°/50%	100°/50%	1 year 100°/85%
1		41.2	-1.6	-0.6	+1.8	55.3	-1.0	-2.1	-1.8
2		39.6	-2.6	-1.2	3.0	49.8	+3.2	+1.6	+5.3
3		42.9	-2.5	- .8	2.1	57.7	-1.4	-1.4	- .1
4		40.1	-1.7	-1.5	2.2	50.4	+ .8	-1.0	+2.3
5		42.0	-1.3	+ .2	3.0	56.0	- .9	-2.4	4.0
6		43.4	-2.2	- .9	2.5	55.0	- .8	+ .1	4.0
7		41.9	-2.4	- .3	2.6	57.1	-2.7	-1.6	-0.8
8		39.6	-1.4	+ .6	3.1	49.9	+2.7	+2.4	+4.8
9		41.8	-1.2	-1.2	1.1	54.4	.5	- .6	.8
10		41.5	-3.7	-2.0	.5	51.6	.5	+ .7	2.6
Average		41.4	-2.1	-0.8	+2.2	53.7	+0.1	-0.4	+2.1

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

STANDARDIZATION OF TEST SAMPLES USED TO SET ORIGINAL SCALES,[1] AND TO CALIBRATE NICKERSON-HUNTER COTTON COLORIMETER [2]

By Dorothy Nickerson, Cotton Division

All early color measurements on cotton were made in terms of Munsell hue, value, and chroma, a color notation that represents practical uniform color spacing. In 1948, when application of the Hunter colorimeter was first proposed for cotton, five Munsell papers in the range of cotton colors were used to peg the level of the cotton measurements. These same papers were used in locating the R_d and b scales for the Nickerson-Hunter Cotton Colorimeter, both Gardner and Spinlab models. In 1948 careful spectrophotometric measurements were made at the National Bureau of Standards on these five papers, and colorimetric data based on them were published (1). [3] Four of these papers have been used not only in setting the original scales of the Nickerson-Hunter Cotton Colorimeter but in calibrating all tiles used since then as secondary standards for individual instrument calibration in Service Test Item No. 23.2 (2). Colorimetric data for these papers, based on 1948 NBS measurements, are listed in table 1.

Technical details involved in establishing the color scales and diagram of the original cotton instrument were reported (3) in detail June 1951. Instrument No. 10002 was used as a Master Instrument, and kept in the laboratory for that purpose. At that time several additional Munsell papers within the color range covered by the cotton grade diagram used on the instrument, plus a few selected porcelain enamels, were carefully spectrophotomered by the late Dr. I. H. Godlove [4] on his Hardy-G.E. instrument with a serious attempt to obtain measurements quite exactly on the 1948 NBS level. Colorimetric data based on these 1950 IHG measurements are listed in table 2. In spite of attempts to obtain results on the same level, in order to put them on the 1948 NBS level, the Godlove measurements require corrections that on the Hunter scales amount to the following: $+0.5R_d$, $+0.1a$, $+0.6b$.

Test Item No. 23.2 (originally numbered 34), was established under the Cotton Fiber and Spinning Testing Service to furnish a "Set of color standards and master diagram for use in calibrating the Nickerson-Hunter Cotton Colorimeter." It was recognized that while the paper samples used in establishing the original scales had a matte surface, which is

---

1/ Procurement and handling details are given in Appendix I.
2/ Under Cotton Fiber and Spinning Testing Service, Test Item No. 23.2.
3/ Underscored figures in parentheses refer to Literature Cited.
4/ General Aniline & Film Laboratories, Easton, Pa.

Table 1.--1948 colorimetric data based on NBS spectrophotometric curves on five papers in the cotton color range

Munsell prod. no.	CIE tristimulus values 1/			Munsell renotations			Hunter coordinates		
	X	Y	Z	H	V	C	%Rd	a	b
1607	68.35	69.81	73.12	2.5Y	8.57	0.8	69.8	-0.2	+6.6
	68.08	69.54	73.11	2.5Y	8.56	0.8	69.5	-0.2	6.4
1608	67.05	68.26	68.95	1.5Y	8.49	1.2	68.3	+0.3	8.4
	67.26	68.48	68.95	1.5Y	8.50	1.2	68.5	0.3	8.6
1604	64.76	65.86	64.04	1.0Y	8.37	1.5	65.9	0.4	10.0
	64.67	65.77	64.04	1.0Y	8.36	1.5	65.8	0.4	10.0
1605	57.62	58.29	47.38	1.0Y	7.95	2.8	58.3	1.1	16.7
	57.97	58.71	47.89	1.0Y	7.98	2.8	58.7	1.0	16.7
1606	49.37	50.13	46.96	1.5Y	7.47	1.6	50.1	0.6	10.5
	49.69	50.44	47.44	1.5Y	7.48	1.6	50.4	0.6	10.4

1/ At the 1959 CIE conference Committee E-1.3.1 recommended that tristimulus values be related to Y = 100. In this way, confusion between X,Y,Z and x,y-data is lessened. The data above follow this convention, thus the decimal point does not agree with its placement in the 1948 publication.

an advantage for color standards, nevertheless, paper standards cannot stand handling and cleaning as well as tile standards. Therefore, in spite of the disadvantage of using glossy or near-glossy surfaces for secondary color standards, it was decided to use a set of four tiles and a central color porcelain enamel plaque. The purpose of these sets was to enable the user of a cotton colorimeter to calibrate his instrument at the level of the instruments in the Cotton Division's laboratories, so that measurements on cottons would always be at the levels of the appropriate cotton grade standards as they are established by the U. S. Department of Agriculture. 5/

In 1952, to supply such calibration sets, 100 central-color porcelain enamel plaques, intended as a match for Munsell paper #1604 which is close to the midpoint of the cotton colorimeter diagram (about R_d = 76.0, +b = 10), were ordered. About the same time 125 each of white, yellow, gray and brown tile were ordered, the colors being selected to enclose the range of cotton colors that the instrument was designed to measure. About the time that Test Item 23.2 was made available, a report dated July 1953 (4) was prepared to accompany the tile sets containing detailed colorimetric data

5/ It is well known that colorimeters of different makes and design cannot be expected to provide exactly the same measurements, chiefly because of differences in spectral sensitivity of sensing elements and even in slight differences in lighting and viewing geometry.

Table 2.--1950 colorimetric data based on spectrophotometric curves for samples on which the Nickerson-Hunter Cotton Colorimeter scales are based 1/

Identification		Based on spectrophotometric data (IGH)* calculated for Illuminant C										
		C.I.E. data					Munsell renotations			Hunter coordinates		
		X	Y	Z	x	y	H	V	C	R_d	a	b
Porcelains -	E_1	76.92	79.72	90.80	0.3109	0.3222	N	9.05	(GY 0.4)	79.7	-2.5	+2.2
	E_5	67.50	69.61	60.74	.3412	.3518	4 Y	8.56	2.2	69.6	-1.6	15.1
	E_8	50.24	49.55	40.58	.3579	.3530	8.5YR	7.43	3.0	49.6	+4.3	15.3
	E_{10}	49.70	51.10	56.68	.3156	.3245	N	7.53	(10Y 0.4)	51.1	-1.0	3.1
Cotton	1604	64.28	65.41	64.23	.3315	.3373	1.5Y	8.34	1.4	65.4	+0.3	9.6
Colors	1605	57.14	57.82	47.65	.3514	.3556	1.5Y	7.93	2.7	57.8	1.1	16.1
NBS (orig.)	1606	48.89	49.65	47.16	.3356	.3408	1.5Y	7.44	1.6	49.6	0.6	9.8
	1607	67.81	69.28	73.35	.3222	.3292	2.5Y	8.54	0.8	69.3	-0.2	5.9
10 YR 9/1	2471	72.09	73.20	76.30	.3253	.3304	10 YR	8.74	1.0	73.2	+0.7	6.9
9/2	2457	70.27	70.84	68.62	.3350	.3378	9 YR	8.62	1.7	70.8	1.7	10.6
8/1	2460	56.66	57.59	59.41	.3263	.3316	1.5Y	7.91	1.0	57.6	0.5	6.8
8/2	2567	58.90	59.53	55.69	.3383	.3419	0.5Y	8.02	1.8	59.5	1.3	11.4
8/3	2459	58.36	58.49	52.11	.3454	.3462	9.5YR	7.97	2.3	58.5	2.4	13.3
8/4	1427	59.18	58.56	46.76	.3598	.3560	8.5YR	7.97	3.3	58.6	4.2	17.6
7/1	2462	44.37	44.98	45.37	.3293	.3339	1 Y	7.13	1.1	45.0	0.8	7.1
7/2	2621	43.90	44.00	39.03	.3459	.3466	10 YR	7.06	2.1	44.0	2.1	11.9
7/3	2461	46.08	45.76	36.37	.3594	.3569	10 YR	7.18	3.0	45.8	3.3	15.8
7/4	1423	47.05	45.89	32.96	.3737	.3645	8.5YR	7.19	3.9	45.9	5.6	19.0
2.5Y 9.25/2	2831	78.92	80.25	78.32	.3323	.3379	1.5Y	9.07	1.4	80.2	0.5	10.8
2.5Y 9/4	2818	70.60	72.25	58.18	.3512	.3594	2.5Y	8.69	2.8	72.2	-0.5	18.8
5 Y 9/3	2552	65.36	67.64	55.09	.3475	.3596	4 Y	8.46	2.6	67.6	-2.1	17.8
7.5YR7/0.5	3097A	41.45	42.25	45.66	.3204	.3266	2.5Y	6.94	0.6	42.2	+0.1	4.0
10 YR7/0.5	--	42.90	43.42	46.38	.3233	.3272	9.5YR	7.02	0.7	43.4	0.9	4.6
5 Y 6.5/0.5	2571	35.94	37.06	38.17	.3233	.3334	4.5Y	6.57	0.8	37.1	-1.2	5.7
N 9.6/	E5462	89.00	91.61	102.21	.3147	.3239	N	9.57	(10Y 0.4)	91.6	-1.5	+3.5
N 9.6/	3327	87.84	90.48	102.90	.3124	.3217	N	9.52	(GY 0.3)	90.5	-1.5	2.3
N 9/	3278	71.40	73.54	81.87	.3148	.3242	N	8.76	(GY 0.4)	73.5	-1.4	3.4
N 8.5/	2725	59.66	61.31	69.30	.3136	.3222	N	8.12	(Y 0.3)	61.3	-1.0	2.3
N 8/	3304	55.11	56.42	65.95	.3105	.3179	N	7.85	(GY 0.1)	56.4	-0.5	0.5
N 7.5/	2726	48.39	49.85	56.81	.3121	.3215	N	7.45	(GY 0.3)	49.8	-1.2	1.7
N 7/	3377	41.96	43.00	50.20	.3105	.3181	N	7.00	(GY 0.1)	43.0	-0.6	0.5
N 6.5/	2351	35.77	36.76	42.95	.3098	.3183	N	6.54	(G 0.1)	36.8	-0.8	0.5

1/ To agree with level of 1948 NBS measurements on original Cotton Colors, the Hunter coordinates must be adjusted by +0.5R_d and +0.6b.

* Through courtesy of I. H. Godlove, General Aniline & Film Corporation Laboratories, Easton, Pa.

for the new tiles, plus data taken at the same time on all previous standardizing materials. The 1953 measurements were made on a GE spectrophotometer at the National Bureau of Standards (NBS Test No. 2.1/G-12210). As in previous tests, all paper samples were backed with black. Colorimetric data based on these NBS 1953 spectrophotometric measurements are given in table 3. To put the Hunter scale data on the level of the 1948 NBS measurements for R_d and b, it is necessary to adjust the 1953 NBS data by $+0.6R_d$ and +0.2b. Based on this work, a diagram containing calibration reference data was prepared for use with Test Item 23.2 (then 34) for the 1950-53 models of the N-H colorimeters which at the time were manufactured only by the Gardner Laboratory.

By 1958 the central color porcelain enamel plaques were reordered, this time with a double coating of enamel for increased durability.

In 1959 Hunter designed a new model instrument, employing phototubes instead of photocells as the sensing device. In the Gardner models, while the scale for +b was linear, the R_d scale was non-linear. The new instrument reproduced these scales as accurately as possible, and used the tile sets for calibration. In 1960 when Spinlab produced a new model instrument patterned after the 1959 phototube design of Hunter, the scales for R_d were made linear.

Measurements of cottons, papers, and tile could not be made on the different models of instruments to agree with each other with a precision equal to that of an individual instrument, or even between instruments of the same model. When the papers and tile were used as calibrating standards and the new instrument was set to measure as close as possible to the level on the Gardner models, then the cottons measured about 0.6b units yellower on the Spinlab model.

It has long been known to colorimetrists that because of differences in geometric and spectral characteristics of instruments and calibrating materials, color measuring instruments of different design do not produce precisely the same answers. A study of the basic differences between these particular instruments was made by contract with R. S. Hunter in 1959 with a view toward developing improved techniques for standardizing cotton colorimeters so that test results would be on the same levels. Hunterlab Report C50, October 15, 1959 (5), show as expected that the disparity was attributed to geometric differences of lighting and viewing and to spectral differences in the sensing elements of the two instruments. Several feasible suggestions for changes that would reduce the differences were made from these comparisons. It was recommended that CIE conditions, $45^\circ 0^\circ$ geometry, Source C, and $\bar{y}$ and $\bar{z}$ be specified for cotton measurements. (The blue filter, and position of filters in the Spinlab instrument approaches these specifications closer than the earlier Gardner instrument.) To avoid errors caused by light penetration into the cotton vs. non-penetration of the tiles, a 1 cm unlighted border around the specimen window was recommended. A shift of calibration points, particularly for the central tile, was found necessary in order that the cottons should read alike on both instruments. It was suggested

Table 3.--1953 detailed colorimetric data based on NBS spectrophotometric curves for samples used in calibrating the Nickerson-Hunter Cotton Colorimeter

Identification		Based on spectrophotometric data (NBS) calculated for Source C										
		C.I.E. data					Munsell renotations			Hunter coordinates		
		X	Y	Z	x	y	H	V	C	R_d	a	b
Porcelains -	E_1	76.91	79.52	90.08	0.3120	0.3226	N	9.04	(GY 0.4)	79.5	-2.1	+2.5
	E_5	68.04	70.18	60.81	.3419	.3526	3.5Y	8.59	2.3	70.2	-1.6	15.5
	E_8	50.26	49.47	39.83	.3601	.3545	8.5YR	7.42	3.1	49.5	+4.5	15.9
	E_{10}	49.62	50.95	55.78	.3174	.3259	7.5Y	7.52	0.5	51.0	-0.8	3.7
Cotton	1604	64.00	65.03	63.43	.3325	.3379	1 Y	8.33	1.5	65.0	+0.5	9.8
Colors	1605	57.24	57.89	47.33	.3523	.3564	1 Y	7.93	2.8	57.9	1.1	16.4
NBS (orig.)	1606	49.05	49.83	46.75	.3368	.3422	1.5Y	7.45	1.7	49.8	0.5	10.3
	1607	67.68	69.07	72.58	.3233	.3300	2.25Y	8.53	0.9	69.1	-0.1	6.4
N-H_1 #117	1604	64.31	65.34	63.94	.3322	.3375	1 Y	8.34	1.4	65.3	0.5	9.6
2 "	1607	67.00	68.31	71.60	.3238	.3302	2 Y	8.50	0.8	68.3	0.1	6.4
3 "	2831	79.52	80.98	78.87	.3322	.3383	1 +Y	9.11	1.5	81.0	0.2	10.9
4 "	1605	58.22	59.00	48.20	.3520	.3566	1.5Y	7.99	2.8	59.0	0.9	16.7
5 "	1606	49.52	50.30	47.19	.3369	.3422	1.5Y	7.48	1.6	50.3	0.5	10.3
N-H_1 #B49	3671	65.25	66.36	63.86	.3338	.3395	1 Y	8.39	1.5	66.4	0.4	10.6
2 "	3692	63.54	64.82	67.98	.3236	.3301	2 Y	8.31	0.8	64.8	-0.02	6.3
3 "	3670	78.39	79.79	76.89	.3335	.3394	1 Y	9.05	1.6	79.8	+0.3	11.4
4 "	3689	64.67	65.33	56,22	.3473	.3508	1 Y	8.34	2.4	65.3	1.4	15.2
5 "	3690	49.26	49.86	47.47	.3360	.3401	1 Y	7.45	1.6	49.9	1.0	9.7
N-H_1 #0-1	3831	63.24	64.00	61.53	.3351	.3390	10 YR	8.27	1.6	64.0	1.1	10.3
2 "	3832	61.52	62.74	65.69	.3239	.3303	2 Y	8.20	0.8	62.7	0.03	6.2
3 "	3833	76.94	78.15	75.02	.3344	.3396	1 Y	8.98	1.7	78.2	0.6	11.5
4 "	3829	63.41	63.87	53.22	.3513	.3538	0.5Y	8.26	2.7	63.9	1.8	16.5
5 "	3830	46.74	47.22	44.97	.3364	.3399	1 Y	7.28	1.5	47.2	1.2	9.5
1953	1	64.23	65.80	65.14	.3291	.3372	2.5Y	8.37	1.3	65.8	-0.6	9.1
Central Color	2	63.96	65.58	65.15	.3285	.3369	3.5Y	8.35	1.3	65.6	-0.7	8.9
P.E.	3	64.02	65.60	64.51	.3298	.3379	2.5Y	8.35	1.3	65.6	-0.7	9.4
1953 Tiles:												
White	1	80.13	81.98	89.70	.3182	.3256	2.5Y	9.15	0.6	82.0	-0.5	4.6
	3	80.87	82.80	90.10	.3187	.3263	3 Y	9.19	0.6	82.8	-0.6	4.9
	6	79.41	81.32	87.84	.3195	.3271	3 Y	9.12	0.7	81.3	-0.6	5.3
Yellow	1	74.36	78.31	66.13	.3398	.3579	8 Y	8.98	2.3	78.3	-4.8	17.4
	3	74.20	78.27	64.45	.3421	.3608	8 Y	8.98	2.6	78.3	-5.1	18.5
	7	74.59	78.41	67.06	.3390	.3563	8 Y	8.99	2.3	78.4	-4.6	16.9
Gray	1	46.61	47.64	53.19	.3161	.3231	N	7.31	(Y 0.4)	47.6	-0.3	2.7
	4	46.14	47.21	53.22	.3148	.3221	N	7.28	(Y 0.3)	47.2	-0.4	2.2
	6	47.65	48.66	53.13	.3189	.3256	2.5Y	7.37	0.6	48.7	-0.1	3.7
Brown	1	37.66	35.85	25.55	.3801	.3619	7.5YR	6.47	3.9	35.8	+7.9	17.5
	4	36.97	35.45	25.56	.3773	.3618	8 YR	6.44	3.8	35.4	7.0	17.1
	6	38.54	36.73	25.28	.3822	.3653	7.5YR	6.54	4.1	36.7	7.8	18.5

that a new central standard, one not metameric with respect to cottons might be an improvement.[6] Methods of making scale adjustments in the instrument were improved.

After making improvements in accord with the recommendations of the Hunterlab report, Spinlab instrument #6377 (selected as the Master Instrument) was calibrated so that cotton measurements on the Spinlab instrument could be maintained on the level previously established for the Gardner models. Cottons measured on the Gardner instrument #10002 in calibration on the #1 Set of tiles, were measured on Spinlab instrument #6377, with scales adjusted so that the R_d and +b readings would be as nearly as possible the same as on the linear scales of the Spinlab instrument. Measurements on the tile sets, papers, enamels, and cottons were all taken into consideration in order to obtain the best match between instruments. Colorimetric measurements on tile set #1 were then recorded on a Master Diagram, based on Spinlab instrument #6377, these measurements to be used as a basis for future calibrations of tile sets (Test Item No. 23.2) that would be required for use on Spinlab type instruments. On this basis a calibration diagram was prepared for the Spinlab instrument, based on the 1953 tile sets.

About 1960 it became necessary to restock the supply of tiles. An order was placed for 4-1/4" wall tile of each of the four colors used on the colorimeter (white, yellow, brown, gray), plus one darker brown (fawn), for use in measuring cotton linters or such other darker samples as might occur in this darker color range. The new tile were slightly thinner than the old, and seemed slightly more porous. Because handling and washing allows the porous tile body to absorb water and thus affect the color, the back and exposed edges of the tile were sprayed with Krylon clear acrylic lacquer.

After spraying, each tile sample was measured on the colorimeter. In each color group most samples measured well within 2%R_d and 1.5b units of each other. Three samples, to represent the range in each of the groups, were then selected for measurement on the spectrophotometer. (The manufacturer noted that the tile in each carton might vary somewhat, in some cases as much as ±2 NBS units of color difference, also that under prolonged exposure to sunlight some colors might change by as much as 1.6 NBS units, a reversible phototropic effect.)

The three tile selected from each group, with all of the standard paper, tile, and enamel plaques previously measured, plus a set of cotton samples, were measured November 1963 by Davidson and Hemmendinger (Easton, Pennsylvania) on their GE spectrophotometer. Table 4 contains detailed

---

6/ The matter of obtaining standard paint, plastic or tile samples non-metameric to cottons is not simple. Late in 1963, Dr. Henry Hemmendinger, after making spectrophotometric measurements on USDA cottons, papers and tiles, agreed to investigate this problem with the help of the D&H COMIC (Color Mixture Computer).

colorimetric data based on these measurements. To put the Hunter scale data on the level of the 1948 NBS measurements for R_d and b, the necessary adjustments, based on remeasurements of the four original cotton color papers, is $-0.1R_d$ and +0.5b.

Measurements in terms of Hunter's R_d and +b on samples used in checking the calibration and scales of the Nickerson-Hunter Cotton Colorimeter over a period of years by measurements in 1948, 1950, 1953, and 1963, are combined in table 5. The data in the left half of the table, based on spectrophotometric measurements, are taken from tables 1-4, adjusted for the difference in instrument levels, so that the averages of the original four cotton colors are in good agreement for the several sets of measurements.

It was possible to use these particular papers in this way for they were already several years old and thus well stabilized for color when the 1948 measurements were made. Based on these adjustments, agreement then can be found for averages of the tile and enamel groups. As for the other groups of papers, painted in succeeding years, results vary. Set #117 papers, which also were seasoned when they were first spectrophotomered, average at about the same +b levels for 1953 and 1963. Papers in Set #B49, produced about 1952, seem to have yellowed slightly between 1953 and 1963, an average difference of +0.3b. The papers in #0-1 set, in which there was very little time for seasoning before their first measurement, have yellowed even more, an average of +0.7b. Most papers in the 10YR group have early production numbers, and these seem to have been well stabilized. For color measurements made on them in 1950, averages for +b are identical for measurements made in 1963, after adjustment for instrument differences. The neutrals, except N6.5/, show considerable yellowing between 1953 and 1963 measurements. The fact that some papers have yellowed as expected, while the stabilized papers, enamels, and tiles have not yellowed, makes it possible to check the 1963 measurements at several slightly different levels. The results are good enough so that it is possible to set calibration points on the Gardner and Spinlab colorimeters for the new series of tiles with considerable confidence that calibrations made with either the old or new series, on either the Gardner or Spinlab models, will produce measurements on cotton sufficiently close to maintain cotton standards at the same levels.

The right half of table 5 contains the colorimeter data. Measurement of the papers and tiles made in 1950 and 1953 on the Gardner model colorimeters are given, also the newly established points for the 1963 tiles. These 1963 points are those at which the tiles measure when the instrument is calibrated so that the original cotton papers and the 10YR series of papers measure as close as possible to the average of the spectrophotometric measurements reported for them, after adjustment to the 1948 level. Measurements for 1963 are given also for the Spinlab instrument, made when the cottons and papers read as closely on the Gardner and Spinlab instruments as it was possible to get them.

Table 4.--1963 detailed colorimetric data based on D&H spectrophotometric curves for samples used in checking the calibration of scales and tile standards for the Nickerson-Hunter Cotton Colorimeter

Identification		Based on spectrophotometric data (D&H) calculated for Source C										
		C.I.E. data					Munsell renotations			Hunter coordinates		
		X	Y	Z	x	y	H	V	C	R_d	a	b
Porcelains -	E_1	77.57	80.18	91.61	0.3111	0.3215	N	9.07	(GY 0.3)	80.2	-2.1	+2.0
	E_6	68.58	70.73	61.89	.3408	.3515	3.5Y	8.62	2.2	70.7	-1.6	15.2
	E_8	50.46	49.73	40.66	.3582	.3531	8.5YR	7.44	2.9	49.7	+4.4	15.4
	E_{10}	50.03	51.35	56.61	.3167	.3250	N	7.54	(5Y 0.5)	51.4	-0.8	3.4
Cotton	1604	65.18	66.17	64.93	.3321	.3371	1 Y	8.38	1.4	66.2	+0.7	9.6
Colors	1605	58.02	58.55	48.27	.3520	.3552	1 Y	7.97	2.8	58.6	1.5	16.3
NBS (orig.)	1606	49.24	49.90	47.50	.3358	.3403	1.5Y	7.45	1.6	49.9	0.8	9.8
	1607	68.45	69.81	73.96	.3225	.3290	1.5Y	8.57	0.8	69.8	0.02	6.0
	*(E5462	88.60	91.05	98.76	.3182	.3270	N	9.54	(7.5Y 0.6)	91.1	-1.3	5.4)
$N\text{-}H_1$ #117	1604	65.07	65.98	65.04	.3318	.3365	0.5Y	8.37	1.4	66.0	+0.8	9.4
2 "	1607	67.69	68.92	72.75	.3233	.3292	1.5Y	8.53	0.8	68.9	0.3	6.1
3 "	2831	80.07	81.48	79.94	.3316	.3374	1 Y	9.13	1.5	81.5	0.4	10.6
4 "	1605	58.84	59.38	49.02	.3518	.3550	1 Y	8.02	2.8	59.4	1.5	16.3
5 "	1606	49.73	50.40	47.89	.3360	.3405	1 Y	7.48	1.6	50.4	0.8	9.8
$N\text{-}H_1$ #B49	3671	65.78	66.87	64.33	.3339	.3395	1.5Y	8.42	1.6	66.9	0.5	10.5
2 "	3692	63.98	65.35	68.30	.3237	.3307	2.5Y	8.34	0.9	65.4	-0.2	6.4
3 "	3670	78.60	79.99	77.17	.3334	.3393	1 Y	9.06	1.6	80.0	+0.4	11.4
4 "	3689	65.03	65.69	56.79	.3468	.3503	1 Y	8.36	2.4	65.7	1.4	15.1
5 "	3690	49.63	50.23	48.01	.3356	.3397	1 Y	7.47	1.6	50.2	1.0	9.6
$N\text{-}H_1$ #0-1	3831	63.07	63.78	60.63	.3364	.3402	10 YR	8.26	1.7	63.8	1.2	10.9
2	3832	61.34	62.59	64.68	.3252	.3318	2 Y	8.19	1.0	62.6	-0.04	7.0
3	3833	75.94	77.01	72.74	.3365	.3412	0.5Y	8.92	1.8	77.0	+0.9	12.2
4	3829	62.42	62.95	52.55	.3508	.3538	1 Y	8.21	2.7	63.0	2.0	16.2
5	3830	47.03	47.52	45.07	.3368	.3404	5 Y	7.30	1.6	47.5	1.2	9.7
10 YR 9/1	2471	72.84	73.86	76.69	.3261	.3306	10 YR	8.77	1.1	73.9	0.9	7.2
9/2	2457	71.20	71.47	68.51	.3372	.3384	8.5YR	8.66	1.9	71.5	2.4	11.0
8/1	2460	57.24	58.07	59.68	.3271	.3318	10 YR	7.94	1.1	58.1	0.7	6.9
8/2	2567	59.81	60.35	56.29	.3390	.3420	10 YR	8.07	1.9	60.4	1.5	11.4
8/4	1427	59.98	59.26	47.36	.3600	.3557	8.5YR	8.01	3.3	59.3	4.4	17.4
7/1	2462	44.88	45.46	45.74	.3298	.3341	0.5Y	7.16	1.2	45.5	0.9	7.1
7/2	2621	44.48	44.51	39.80	.3454	.3456	9.5YR	7.10	2.1	44.5	2.3	11.7
7/3	2461	46.64	46.23	36.78	.3597	.3566	9.5YR	7.21	3.0	46.2	3.5	15.8
7/4	1423	47.97	46.69	33.70	.3737	.3637	8.5YR	7.24	3.9	46.7	5.8	19.1
2.5Y 9/4	2818	71.05	72.64	58.34	.3517	.3596	2.5Y	8.71	2.9	72.6	-0.4	19.0
5 Y 9/3	2552	66.50	68.47	55.31	.3495	.3598	3.25Y	8.50	2.8	68.5	+1.4	18.2
5 Y 6.5/0.5	2571	36.40	37.45	38.59	.3237	.3331	5.5Y	6.60	0.8	37.5	-1.0	5.7

* Belongs with N group, page 9.

Table 4.--Continued

Identification		Based on spectrophotometric data (D&H) calculated for Source C										
		C.I.E. data					Munsell renotations			Hunter coordinates		
		X	Y	Z	x	y	H	V	C	R_d	a	b
N 9.6/	3327	87.40	89.97	98.53	0.3168	0.3261	N	9.50	(GY 0.6)	90.0	-1.5	4.8
N 9/	3278	71.55	73.54	79.96	.3179	.3268	N	8.76	(Y 0.6)	73.5	-1.2	4.7
N 8.5/	2725	60.17	61.72	69.10	.3150	.3232	N	8.15	(Y 0.3)	61.7	-0.8	2.8
N 8/	3304	55.54	56.89	65.48	.3122	.3198	N	7.87	(GY 0.2)	56.9	-0.6	1.3
N 7.5/	2726	49.35	50.77	57.73	.3126	.3216	N	7.51	(GY 0.3)	50.8	-1.1	1.9
N 7/	3377	42.73	43.75	50.23	.3126	.3200	N	7.05	(Y 0.2)	43.8	-0.5	1.3
N 6.5/	2351	36.50	37.42	43.73	.3102	.3181	N	6.59	(G 0.1)	37.4	-0.6	0.5
1953	1	64.42	66.04	65.87	.3281	.3364	3 Y	8.38	1.2	66.0	-0.7	8.8
Central Color	2	64.48	66.15	66.33	.3274	.3358	3.5Y	8.38	1.2	66.2	-0.8	8.6
P.E.	3	64.59	66.21	65.76	.3286	.3368	3 Y	8.39	1.3	66.2	-0.7	9.0
1953 Tiles:												
White	1	81.02	82.87	91.54	.3172	.3244	4.5Y	9.19	0.5	82.9	-0.4	4.1
	3	81.89	83.80	92.11	.3176	.3250	2.5Y	9.23	0.6	83.8	-0.5	4.4
	6	80.45	82.35	89.88	.3184	.3259	4 Y	9.17	0.6	82.4	-0.6	4.8
Yellow	1	74.96	79.00	67.40	.3386	.3569	8.5Y	9.02	2.2	79.0	-5.1	17.1
	3	74.90	79.03	65.64	.3411	.3599	8.5Y	9.02	2.5	79.0	-5.3	18.3
	7	75.18	79.16	68.64	.3372	.3550	8.5Y	9.02	2.1	79.2	-5.0	16.4
Gray	1	46.91	47.92	53.88	.3154	.3222	N	7.32	(Y 0.3)	47.9	-0.2	2.3
	4	46.46	47.52	54.01	.3139	.3211	N	7.30	(Y 0.3)	47.5	-0.3	1.8
	6	48.06	49.07	54.07	.3178	.3245	N	7.40	(Y 0.5)	49.1	-0.1	3.3
Brown	1	37.79	36.06	25.81	.3792	.3618	7.5YR	6.49	3.8	36.1	+7.4	17.5
	4	37.22	35.74	26.13	.3756	.3607	7.5YR	6.46	3.7	35.7	6.7	16.7
	6	38.77	37.03	25.91	.3812	.3641	7.5YR	6.56	4.0	37.0	7.4	18.2
1963												
Central Color	1	62.85	64.46	64.96	.3269	.3352	3 Y	8.29	1.2	64.5	-0.8	8.2
P.E.	2	62.12	63.68	64.05	.3272	.3354	3.5Y	8.25	1.2	63.7	-0.7	8.3
	3	62.00	63.57	63.85	.3273	.3356	3.5Y	8.25	1.2	63.6	-0.7	8.4
1963 Tiles:												
White	1	81.79	83.85	91.92	.3176	.3256	5 Y	9.23	0.6	83.9	-0.8	4.6
	2	81.57	83.70	91.22	.3180	.3263	5 Y	9.23	0.6	83.7	-1.0	4.9
	3	81.26	83.36	90.72	.3182	.3265	6 Y	9.21	0.6	83.4	-0.9	5.0
Yellow	1	74.13	77.73	66.32	.3398	.3563	7.5Y	8.96	2.3	77.7	-4.3	17.0
	2	74.55	78.30	66.82	.3394	.3564	7.5Y	8.98	2.2	78.3	-4.5	16.9
	3	74.03	77.71	65.92	.3401	.3570	7.5Y	8.96	2.3	77.7	-4.4	17.3
Gray	1	47.09	48.08	54.25	.3152	.3218	N	7.34	(Y 0.3)	48.1	-0.1	2.2
	2	47.06	47.98	53.59	.3166	.3228	N	7.33	(Y 0.4)	48.0	+0.05	2.7
	3	47.64	48.53	53.65	.3180	.3239	N	7.36	(Y 0.5)	48.5	0.1	3.2
Brown	1	39.67	37.84	26.52	.3813	.3637	7.5Y	6.62	4.1	37.8	7.6	18.3
	2	40.24	38.31	26.68	.3824	.3640	7.5Y	6.66	4.1	38.3	7.8	18.5
	3	40.25	38.23	26.18	.3846	.3653	7.5Y	6.65	4.3	38.2	8.1	19.0
Med. Brown	1	35.45	34.70	30.08	.3537	.3462	7.5Y	6.38	2.5	34.7	4.5	11.6
	2	36.13	35.46	31.48	.3505	.3440	7.5Y	6.44	2.3	35.5	4.3	10.9
	3	36.38	35.59	30.32	.3556	.3479	7.5Y	6.45	2.6	35.6	4.6	12.3

Table 5.--Measurements in terms of Hunter's R_d and +b on samples used in checking calibration scales of the Nickerson-Hunter Cotton Colorimeter on which both spectrophotometric and colorimetric data are available

Identification		From spectrophotometric data: 1948 Orig. NBS 1/		1950 IHG-Adj. to NBS 2/		1953 NBS Adj. 3/		1963 D&H Adj. 4/		N-H Colorimetric data: Gardner model 1950		Gardner model 1963		Gardner model 1963		Spinlab model 1963	
		%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b
Porcelains -	E_1			80.2	2.8	80.1	2.7	80.1	2.5	79.8	2.8	80.0	3.1	80.0	3.1	80.0	2.4
	E_5			70.1	15.7	70.8	15.7	70.6	15.7	71.9	15.3	71.3	15.1	72.0	15.1	71.5	14.6
	E_8			50.1	15.9	50.1	16.1	49.6	15.9	51.2	16.5	51.0	16.4	50.9	16.2	50.9	15.9
	E_{10}			51.6	3.7	51.6	3.9	51.3	3.9	52.0	3.9	51.4	4.0	51.6	4.0	51.8	3.6
Average.......				63.0	9.5	63.2	9.6	62.9	9.5	63.7	9.6	63.4	9.6	63.6	9.6	63.6	9.1
Cotton	1604	65.8	10.0	65.9	10.2	65.6	10.0	66.1	10.1	66.0	10.1	65.8	10.2	65.4	10.2	65.6	9.9
colors	1605	58.5	16.7	58.3	16.7	58.5	16.6	58.5	16.8	58.8	17.0	58.5	16.8	58.5	16.9	58.4	16.5
NBS (orig.) 1/	1606	50.2	10.4	50.1	10.4	50.4	10.5	49.8	10.3	50.5	10.5	49.9	10.4	49.9	10.4	50.0	10.4
	1607	69.6	6.5	69.8	6.5	69.7	6.4	69.7	6.5	70.0	6.8	69.4	6.6	69.6	6.8	69.3	6.4
Average.......		61.0	10.9	61.0	11.0	61.0	10.9	61.0	10.9	61.3	11.1	60.9	11.0	60.9	11.1	60.8	10.8
N-H_1 #117	1604					65.9	9.8	65.9	9.9			65.6	10.2	65.8	10.1	65.5	9.8
2 "	1607					68.9	6.6	68.8	6.6			69.0	6.8	69.2	6.9	68.8	6.5
3 "	2831					81.6	11.1	81.4	11.1			81.5	11.1	81.8	11.3	81.5	11.0
4 "	1605					59.6	16.9	59.3	16.8			59.5	16.9	59.6	16.7	58.9	16.4
5 "	1606					50.9	10.5	50.3	10.3			50.1	10.6	50.4	10.4	50.4	10.3
Average.......						65.4	11.0	65.1	10.9			65.1	11.1	65.4	11.1	65.0	10.8
N-H_1 #849	3671					67.0	10.8	66.8	11.0			66.4	10.8	66.6	11.3	66.5	11.2
2 "	3692					65.4	6.5	65.3	6.9			64.9	6.6	65.0	7.4	65.2	7.2
3 "	3670					80.4	11.6	79.0	11.9			80.6	11.4	80.5	12.0	80.2	11.7
4 "	3689					65.9	15.4	65.6	15.6			65.7	15.4	65.9	15.7	65.7	15.5
5 "	3690					50.5	9.9	50.1	10.1			50.0	9.7	50.2	10.0	50.2	10.0
Average........						65.8	10.8	65.4	11.1			65.5	10.8	65.6	11.3	65.6	11.1
N-H_1 #0-1	3831					64.6	10.5	63.7	11.4			64.0	10.7	63.7	11.6	63.9	11.2
2 "	3832					63.3	6.4	62.5	7.5			62.7	6.7	62.3	7.7	62.5	7.5
3 "	3833					78.8	11.7	76.9	12.7			78.9	11.8	77.4	12.7	77.3	12.5
4 "	3829					64.5	16.7	62.9	16.7			64.0	16.2	63.2	16.7	63.4	16.4
5 "	3830					47.8	9.7	47.4	10.2			47.2	9.6	47.1	10.1	47.5	10.2
Average........						63.8	11.0	62.7	11.7			63.4	11.0	62.7	11.8	62.9	11.6
10 YR 9/1	2471			73.7	7.5			73.8	7.7	74.0	7.7	73.4	7.7	73.8	8.0	74.1	7.4
9/2	2457			71.3	11.2			71.4	11.5	72.4	11.3	71.7	11.3	71.9	11.8	72.0	11.4
8/1	2460			58.1	7.4			58.0	7.4	57.8	7.6	57.9	7.1	58.2	7.3	58.3	7.1
8/2	2567			60.0	12.0			60.3	11.9	60.0	12.1	60.0	12.2	60.1	12.3	60.0	11.9
8/4	1427			59.1	18.2			59.2	17.9	59.4	18.3	59.0	18.2	60.2	18.0	59.7	17.7
7/1	2462			45.5	7.7			45.4	7.6	45.8	7.6	45.3	7.6	45.0	7.6	45.4	7.5
7/2	2621			44.5	12.5			44.4	12.2	45.0	12.5	44.5	12.3	44.4	12.3	44.7	12.2
7/3	2461			46.3	16.4			46.1	16.3	47.2	16.8	46.5	16.6	46.7	16.7	46.8	16.4
7/4	1423			46.4	19.6			46.7	19.6	46.8	19.8	46.2	19.7	47.0	19.6	46.9	19.4
Average.......				55.0	12.5			56.1	12.5	56.5	12.6	56.1	12.5	56.4	12.6	56.4	12.3
2.5 Y 9/4	2818			72.8	19.4			72.5	19.5	73.2	19.3	72.4	19.4	73.0	19.4	72.5	19.2
5 Y 9/3	2552			68.1	18.4			68.4	18.7	68.8	18.5	67.7	18.3	68.2	18.3	67.8	18.0
5 Y 6.5/0.5	2571			37.6	6.3			37.4	6.2	37.5	5.6	36.5	5.3	37.1	5.6	38.0	5.8
Average				59.5	14.7			59.4	14.8	59.8	14.5	58.9	14.3	59.4	14.4	59.4	14.3

1/ Published, JOSA, 40, p. 87 (1950).

2/ Includes adjustment of +0.5, +0.6 for R_d and +b, over orig. measurements. See Table 5, June 1931, report on Calibration of Scales.

3/ Includes adjustment of +0.6 R_d, +0.2b to agree with level of NBS 1948 measurements.

4/ Includes adjustment of -0.1R_d, +0.2b to agree with level of NBS 1948 measurements.

Table 5.--Continued

Identification		From spectrophotometric data: 1948 Orig. NBS 1/		1950 IHC-adj. to NBS 2/		1953 NBS adj. 3/		1963 D&H adj. 4/		N-H colorimetric data: Gardner model 1950		Gardner model 1953		Gardner model 1963		Spinlab model 1963	
		%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b	%R_d	+b
N 9.6/	E5462			92.1	4.1			91.0	5.9					91.4	6.9	91.0	6.5
N 9.6/	3327			91.0	2.9			89.1	5.3					90.4	5.2	89.5	4.6
N 9/	3278			74.0	4.0			73.4	5.2					73.3	5.5	73.6	5.0
N 8/	3304			56.9	1.1			56.8	1.8					55.9	2.2	56.0	1.8
N 7/	3377			43.5	1.1			43.7	1.8					42.9	1.5	43.0	1.3
N 6.5/	2351			37.3	1.1			37.3	1.0					37.0	0.7	37.3	0.4
1953	1					66.4	9.3	65.9	9.3			66.2	9.5	67.6	9.5	67.2	9.2
Central color	2					66.2	9.1	66.1	9.1			66.1	9.3	66.9	9.3	66.7	9.0
P.E.	3					66.2	9.6	66.1	9.5			66.3	9.8	67.1	9.6	66.7	9.2
1953 Tiles:																	
White	1					82.6	4.8	82.8	4.6			83.3	4.8	83.8	4.9	83.5	4.2
	3					83.4	5.1	83.7	4.9			85.2	5.1	85.0	5.1	84.5	4.5
	6					81.9	5.5	82.3	5.3			83.2	5.6	83.1	5.6	83.1	5.0
Yellow	1					78.9	17.6	78.9	17.6			80.2	17.0	80.5	16.8	79.7	16.6
	3					78.9	18.7	78.9	18.8			80.6	18.0	80.7	17.8	79.8	17.7
	7					79.0	17.1	79.1	16.9			80.5	16.4	80.4	16.2	80.0	16.1
Gray	1					48.2	2.9	47.8	2.8			48.0	3.0	48.6	2.9	48.5	2.6
	4					47.8	2.4	47.4	2.3			47.4	2.1	48.0	2.1	47.8	1.8
	6					49.3	3.9	49.0	3.8			48.5	3.6	49.1	3.6	48.6	3.4
Brown	1					36.4	17.7	36.0	18.0			36.6	17.6	37.0	17.5	37.2	17.2
	4					36.0	17.3	35.6	17.2			36.5	17.4	36.8	16.9	37.1	17.5
	6					37.3	18.7	36.9	18.7			37.2	18.8	38.0	18.4	38.0	18.8
Average.......						62.6	10.6	62.4	10.6			63.1	10.5	63.5	10.4	63.2	10.3
1963	1							64.4	8.7					65.6	9.1	65.3	8.7
Central color	2							63.6	8.8					65.1	9.0	64.9	8.8
	3							63.5	8.9					64.9	9.3	64.7	9.0
1963 Tiles:																	
White	1							83.8	5.1					85.6	5.3	84.9	4.7
	2							83.6	5.4					85.7	5.7	85.0	5.2
	3							83.4	5.5					85.4	5.8	84.8	5.2
Yellow	1							77.6	17.5					79.7	16.8	78.9	16.5
	2							78.2	17.4					80.2	16.8	79.4	16.8
	3							77.6	17.8					79.9	17.1	79.4	17.0
Gray	1							48.0	2.7					47.2	2.7	47.2	2.5
	2							47.9	3.2					47.2	3.1	47.4	3.0
	3							48.5	3.7					48.1	3.7	48.0	3.5
Brown	1							37.7	18.8					36.6	18.7	37.3	19.6
	2							38.2	19.0					36.8	19.1	37.5	20.0
	3							38.1	19.5					36.8	19.4	37.5	20.6
Med. Brown	1							34.6	12.1					33.3	11.6	34.0	12.8
	2							35.4	11.4					33.8	11.1	34.4	12.2
	3							35.5	12.8					33.8	12.2	34.5	13.2
Average.......								57.8	11.0					58.1	10.9	58.1	11.1

Based on these calibrations, measurements for six cotton samples are given in table 6 as read on the standardizing instruments, Gardner No. 10002 and Spinlab No. 6377, without adjustment for any yellowness difference between instruments such as was found necessary in 1959 and 1960 when the Spinlab instruments were first calibrated. (Colorimetric data computed from spectrophotometric curves made on these six cotton samples are discussed in Appendix II.)

Table 6.--Measurements on six cotton samples on Gardner and Spinlab models of the Nickerson-Hunter Cotton Colorimeter based on the 1963 established calibration

Cotton sample number	Gardner #10002		Spinlab #6377	
	R_d	+b	R_d	+b
1	81.4	9.8	81.3	10.0
2	78.6	9.7	78.3	9.8
3	71.0	8.0	70.8	8.2
4	56.7	6.5	57.0	6.9
5	69.6	12.9	69.5	13.0
6	58.9	12.4	58.2	12.7
Average	69.4	9.9	69.2	10.1

While the cotton measurements on the Spinlab compared to the Gardner instrument may be very slightly yellower (+0.2b) and the average on the papers slightly less yellow (-0.3b), the agreement of each instrument with spectrophotometric measurements seems as good as can be expected. Therefore, without further adjustment, new calibration diagrams have been prepared for use with the new series of tiles in Test Item 23.2, each containing calibration reference data based on spectrophotometric measurements made in 1948, 1950, 1953, and in 1963 when samples of the new tile supply were measured. One diagram has been prepared for calibrating Gardner models of the Nickerson-Hunter Cotton Colorimeters, the other for calibrating Spinlab models.

General Discussion

As stated earlier in this report, and more fully in previous reports (3, 4), colorimetry still has several unsolved problems. The experienced colorimetrist has learned to work with instruments of single design as a single unit, and not try to push too hard for 100 percent correlations in converting all slight deviations on individual samples. Too many unknowns are involved regarding exact geometrical and spectral characteristics of lighting and viewing conditions, and of sample preparation and presentation, even for instruments that are intended to be exactly the same. For any cotton colorimeter, the most important thing to remember is that answers must

provide cotton measurements that are closely enough on the same level as those of the Master instrument used in setting the cotton standards so that no differences will be tolerated between instruments in cotton color measurements that will be significant in terms of the color of the Universal Cotton Grade Standards as established in 1953, and established again in 1963 without change in the color-grade diagram.

The color-grade diagrams on the Gardner and Spinlab models of the N-H Cotton Colorimeter, with their provision for large sample measurement, are what make each of these two instruments a cotton colorimeter. Without the diagram they would do nothing but provide directly indicating, automatic, small-difference colorimeters for use in the range of near-white colors. The measurement levels would depend on the method and means of calibration. For the Cotton Colorimeter a calibration method that uses paper and tile samples is spelled out in this report with more than usual detail. The diagram includes a plot of the various cotton grades by color.

No calibration of these instruments is complete without a check on cottons to make sure that in calibrating on the 23.2 set of tiles there are no conditions between the instrument being calibrated and the Cotton Division's Master instrument of the same model, that vary enough to cause a difference in the level of measurements of cottons in comparison to the level of papers and tiles as reported here for the Master instrument. For making such checks with cottons, Test Items 23 and 23.1 are available. Because the color of cotton changes with time and the condition of temperature and humidity under which it is held, cottons used as checks must be remeasured periodically on a calibrated instrument. With this precaution, occasional resort to use of check cottons, as well as the regular and consistent use of calibrating tiles, is recommended.

Literature Cited

(1) Nickerson, D., Munsell Renotations Used to Study the Color Space of Hunter and Adams. J. Opt. Soc. Am., 40:85-88 (1950).

(2) U.S.D.A., Service and Regulatory Announcement No. A.M.S. 178, Regulations of the Department of Agriculture for Cotton Fiber and Processing Tests, Revised August 1960.

(3) Nickerson, D., Calibration of Scales on the Nickerson-Hunter Cotton Colorimeter. USDA, Cotton Branch, P.M.A., 15 pp., mimeographed for Administrative Use (June 1951).

(4) Nickerson, D., Basis for Calibration Data Supplied With Color Standards Under Cotton Fiber and Spinning Testing Service Test Item No. 34. USDA, Cotton Branch, P.M.A., 6 pp., mimeographed for Administrative Use (July 1953).

(5) Hunter, R. S., Improved Techniques for the Standardization of Cotton Colorimeters. Hunterlab Report C50, Oct. 15, 1959. (Prepared in fulfillment of Contract No. 12-25-100-6448, June 11, 1959.)

APPENDIX I

Procurement and Handling Details:

a. Porcelain enamel plaques were purchased from Erie Ceramic Arts Co., 3120 West 22nd St., Erie, Pennsylvania (attn. Mr. H. E. Schabacker).

Plaques were reordered in 1958 on the basis of a double coating of enamel to insure greater durability. Two hundred and fifty were ordered, color to approximate that of the old plaque, at $1.75 each.

b. Tiles were purchased from the Cambridge Tile Company, through Dr. I. H. Balinkin.

In March 1961 a replacement purchase was made from Cambridge Tile Company. The order, following correspondence with Dr. I. H. Balinkin, was for 300 4-1/4" wall tile of white, yellow, brown, gray, plus 100 medium brown, "fawn" color. The price was just under 7 cents each. The new tile, packed in cartons of 50 each, were thinner than the original set. After color measurements were made on them, the tile were repacked in cartons of 25 each for ease of handling.

c. The last order for boxes designed to hold one set of calibrating tiles, as sold under Service Test Item 23.2, was for 25 at $4.55 each, from the Statolet Corp., attn. Mr. Walter Trepp, Box 865, Guttenberg, N. J. In earlier years they were ordered from a jewelry case manufacturer in Buffalo, but the price went up so high that we located the Statolet Corp. which makes similar type boxes for both Hunterlab and for N.B.S.

d. In preparing plastic diagrams for the instrument it is important to make sure that the dimensions on original drawings are accurate and that they be reproduced as contact prints to make sure that they are exact size. They should be made on dimensionally stable film. Paper work sheets will change dimensions slightly. Therefore in reprinting copies of work sheets, care should be taken to make them from dimensionally stable film negatives in order to maintain a close fit.

APPENDIX II

At the time that spectrophotometric measurements were made by D&H on paper and tile samples, measurements were also made through glass on six cotton samples. The glass was the same as that used in the window of the colorimeter, specified as a water-white plate glass.

On the colorimeter, measurements are made through a glass window but the effect of the glass is canceled out by setting scale levels at the level of standardizing papers and tiles as they are spectrophotometered directly without glass. For repeatable spectrophotometric measurements on raw cottons it is necessary to measure the samples behind glass. This means that the difference in measurements with and without glass must account, not only for the loss of light as it passes through the glass surface four times in making a measurement of the cotton color, but also for any trace of color present in the glass.

Table 7 provides colorimetric data based on spectrophotometric measurements of these six cottons, computed in the same manner as the data in table 4. Table 8 lists measurements on these cottons in terms of Hunter's R_d and +b as measured directly on the colorimeters, excluding the effect of glass, and converted from the spectrophotometric measurements, including the effect of glass.

Table 7.--1963 detailed colorimetric data based on D&H spectrophotometric curves for six cotton samples measured behind glass

Identification	Based on spectrophotometric data (D&H) calculated for Source C										
	C.I.E. data					Munsell renotation			Hunter coordinates		
	X	Y	Z	x	y	H	V	C	R_d	a	b
Cottons* 1	64.76	66.30	64.68	0.3308	0.3387	3Y	8.39	1.4	66.3	-0.5	+9.9
2	62.17	63.58	61.95	.3312	.3387	3Y	8.25	1.4	63.6	-0.4	9.8
3	57.23	58.70	58.99	.3272	.3356	4Y	7.98	1.2	58.7	-0.8	8.0
4	42.05	42.85	42.69	.3296	.3358	2Y	6.98	1.2	42.8	+0.1	7.4
5	58.43	59.20	53.59	.3412	.3458	1Y	8.01	2.0	59.2	+0.9	12.6
6	48.12	48.55	42.75	.3451	.3482	1Y	7.39	2.2	48.6	+1.4	12.6

* Measured through glass identical with that used in Cotton Colorimeter. The difference, however, is that in the Cotton Colorimeter the calibration is made with glass behind <u>all</u> samples, thus canceling the effect of the glass on the level of color measurements. For example, while the Munsell papers used in calibration are measured on the colorimeter through glass, the measurements used for setting the scale levels is the level <u>without</u> glass, based on spectrophotometric measurements made without glass.

The difference in +b values between measurements made on the spectrophotometer and those made on the Gardner and Spinlab colorimeters is within 0.1 +b units for samples 1 and 2, two high grade cottons; for sample 3, a Strict Low Middling, it is within 0.2 +b; for samples 5 and 6, which are Tinged grades, it is within 0.4 +b. The greatest difference is for sample 4, a Good Ordinary, for which the Gardner model and spectrophotometric measurements differ by 0.9 +b; for the Spinlab model and spectrophotometer the difference is 0.5 +b. This does not seem unduly large when it is remembered that cotton samples in the lower grades are more variable, and that the spectrophotometer measured a circle not over 1-1/4" diameter, compared to a 4" x 4" sample measured on the colorimeters. (The b levels do differ from the 0.5 adjustment necessary to put spectrophotometric measurements on the papers at the level of previous years, but since the truest relationship should exist in the case of papers of near-matte surface, the calibration must be set at the level of best agreement for the papers, not for the enamels or tiles.)

Table 8.--Measurements on cottons and one paper sample measured behind glass on colorimeter and spectrophotometer

Sample ident.	from colorimeter				from spectrophotometer (D&H)				
	Gardner		Spinlab		directly computed		adjusted to 118% 1/	residual difference Gardner	residual difference Spinlab
	R_d	b	R_d	b	R_d	b	R_d	R_d	R_d
Cotton 1	81.4	9.8	81.3	10.0	66.3	9.9	78.2	-3.2	-3.1
2	78.6	9.7	78.3	9.8	63.6	9.8	75.0	-3.6	-3.3
3	71.0	8.0	70.8	8.2	58.7	8.0	69.3	-1.7	-1.5
4	56.7	6.5	57.0	6.9	42.8	7.4	50.5	-6.2	-6.5
5	69.6	12.9	69.5	13.0	59.2	12.6	69.9	+0.3	+0.4
6	58.9	12.4	58.2	12.9	48.6	12.6	57.3	-1.6	+0.9
Paper std. 117-1604	65.8	10.1	65.5	9.8	54.0	9.7	63.7	-2.1	-1.8

1/ Loss is about 4 percent for each glass boundary crossed. Thus D&H cotton measurements through clear plate glass should be about 85 percent of the colorimeter measurements. This accounts for loss at four boundaries. To discount the effect of the glass the cotton measurements should be about 118 percent of measurements through clear glass. The remaining difference includes any failure of the glass to be completely transmitting and spectrally non-selective. The glass used transmits between 90.5 and 91.2 percent at wavelengths 400-700 nm.)

As for the differences in Y measurements for cottons between those measured on the spectrophotometer through glass and those measured on the colorimeters, these exceed somewhat the reduction necessary to account for the loss of transmission as light passes through four boundary surfaces. For reference, the curve of spectral transmission for the glass is given (see figure 3), but no further attempt is made here to resolve these differences. See General Discussion, page 12.

For purposes of comparison and record, spectrophotometric curves are included in four attached figures. Those shown in figure 1 are for the four Munsell papers originally used for calibration, and in figure 2 for the 1953 and 1963 sets of enamels and tiles. As can be seen, the 1963 replacements for the 1953 white and yellow tiles have curve shapes that are reasonably alike, the central color is clearly darker, the 1963 gray is no longer as non-selective as it was in 1953 (which makes the grays metameric), the 1963 brown is lighter than the 1953 browns. Figure 3 shows spectrophotometric curves of the six cottons as measured through glass, and a transmission curve for the glass. Figure 4 shows spectrophotometric curves of seven cottons measured in 1959 without glass, selected from their colorimeter measurements to be approximately the same as the six measured in 1963. While the level is higher for the 1959 spectrophotometric measurements, this evidently is because the surfaces measured without glass provided shadows which absorb some of the light. This differs from a flat surface provided under pressure, and results in calculated data for the 1959 measurements that are not as high as they are by either colorimeter or visual methods.

The spectrophotometric curves in these figures make it clear that considerable metamerism is involved between the cottons and the tile and paper standards, for the general shape of the curves for the natural fibers and those based on pigmented coatings are quite different in character. It would help solve many problems in instrumental and visual colorimetry if secondary standards could be prepared in papers, enamels, tiles, or plastics that would be non-metameric to the product with which they are used, whether in color matching or in calibrating an instrument. Any color shift caused by spectral differences in lighting or viewing conditions would be more nearly the same in direction and amount for standard and product when the curves have a generally similar shape than they are when product and standards are metameric. [6/] (Metameric pairs would provide an even better check.)

Figure 1.--Spectrophotometric curves for four special Munsell papers in cotton color range that were used in original calibration of the N-H Cotton Colorimeter.

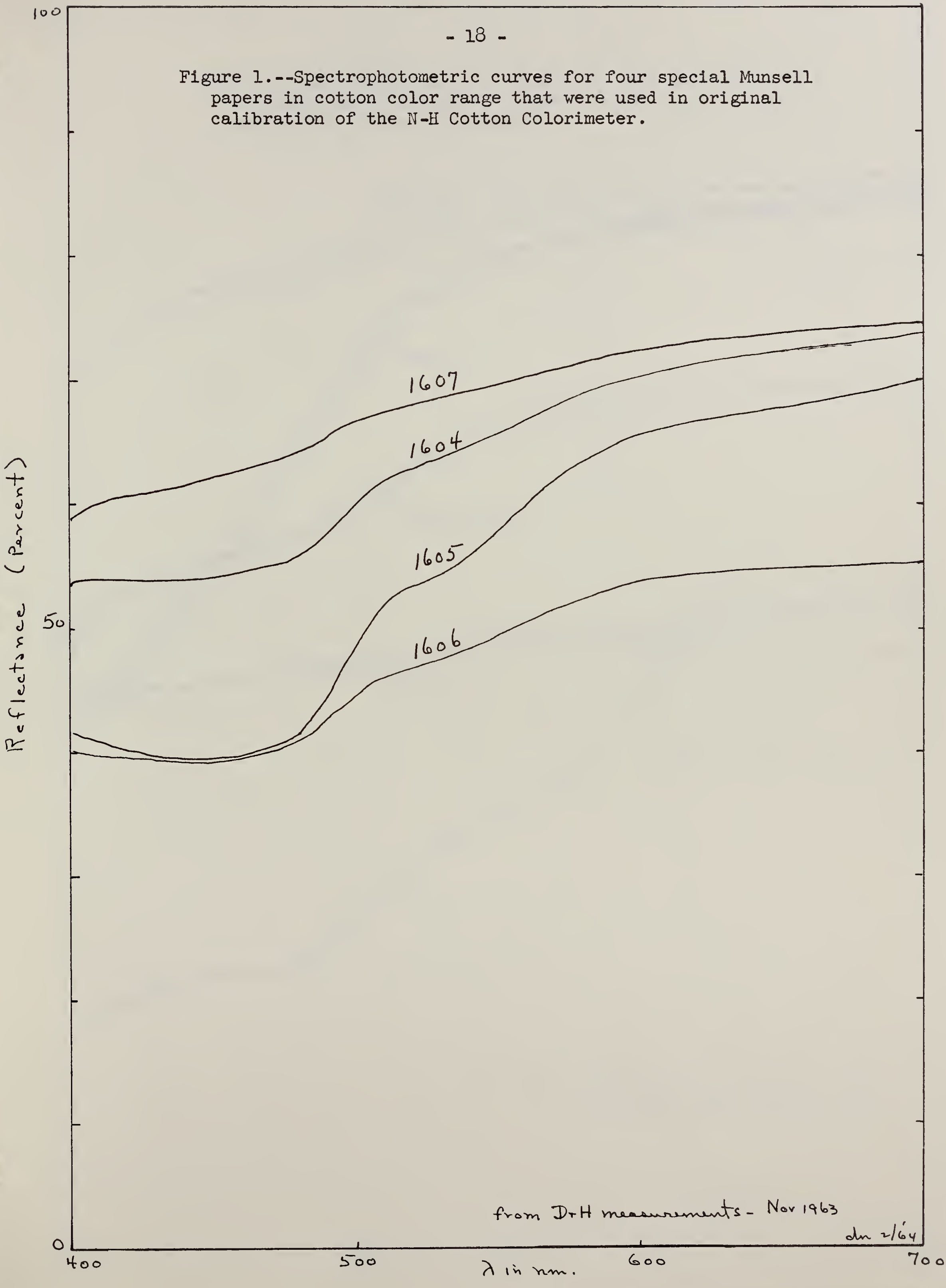


Figure 2.--Spectrophotometric curves for 1953 and 1963 sets of enamels and tiles used in Service Test 23.2 for calibrating N-H Cotton Colorimeter.

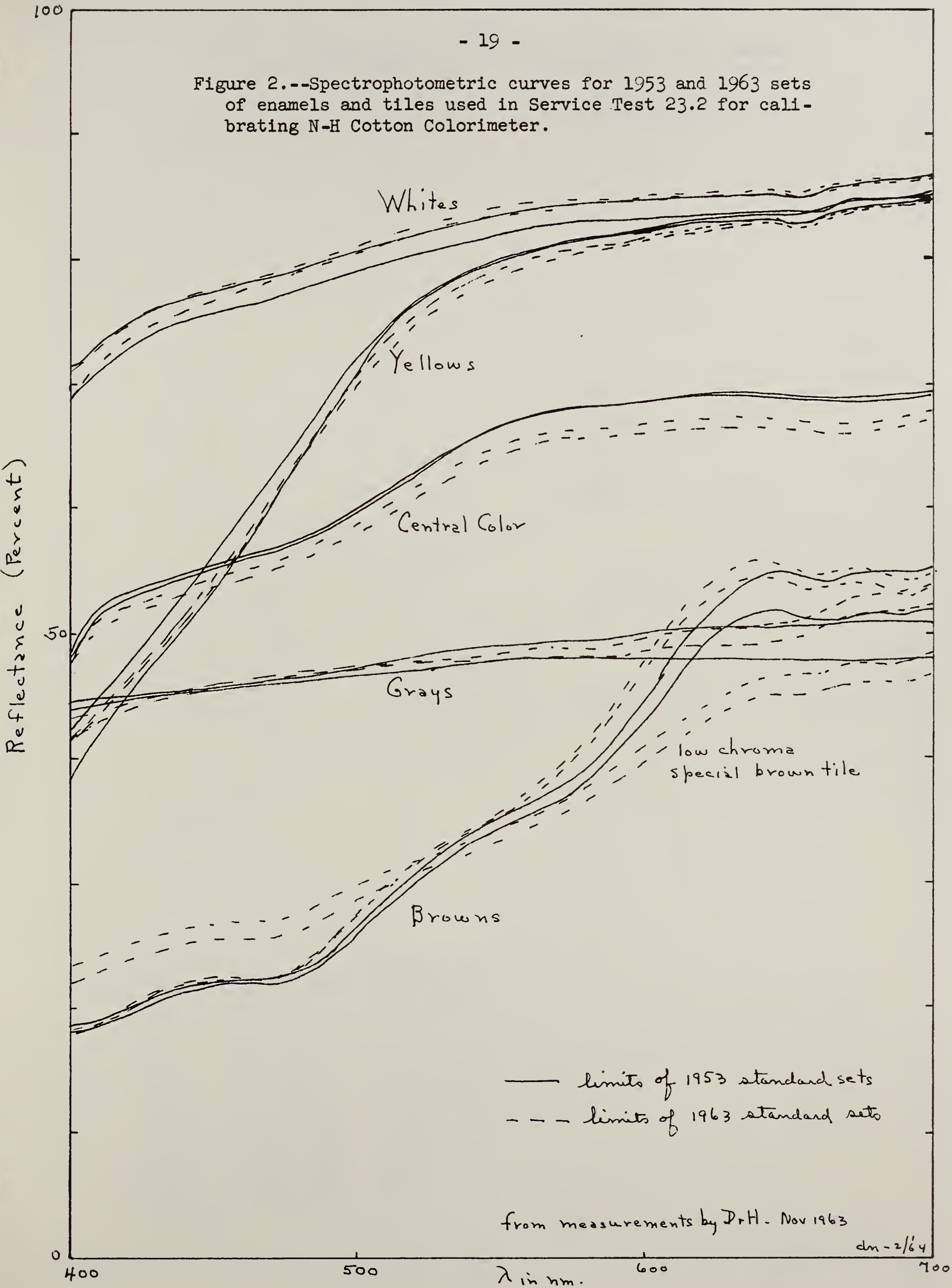
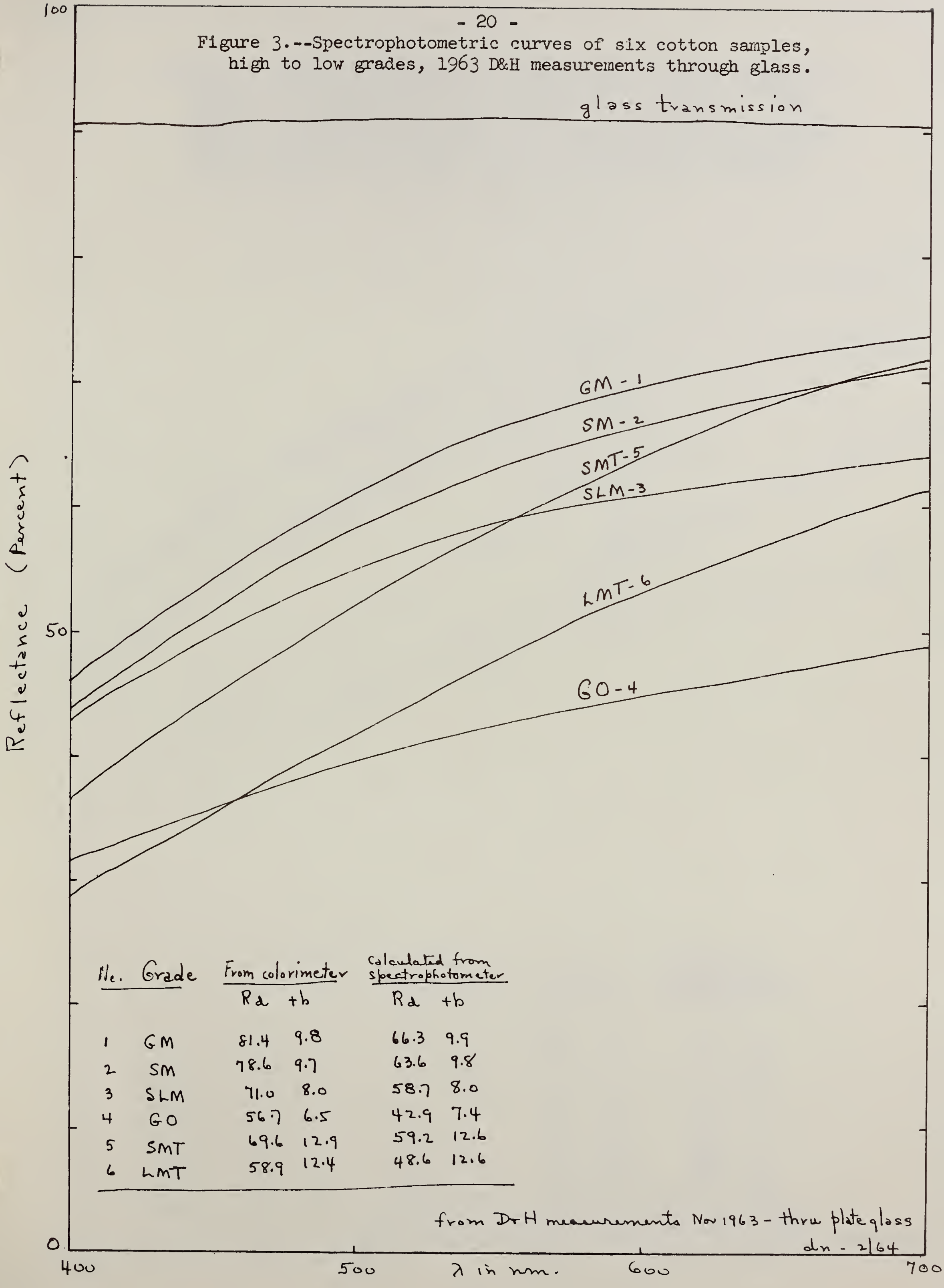


Figure 3.--Spectrophotometric curves of six cotton samples, high to low grades, 1963 D&H measurements through glass.

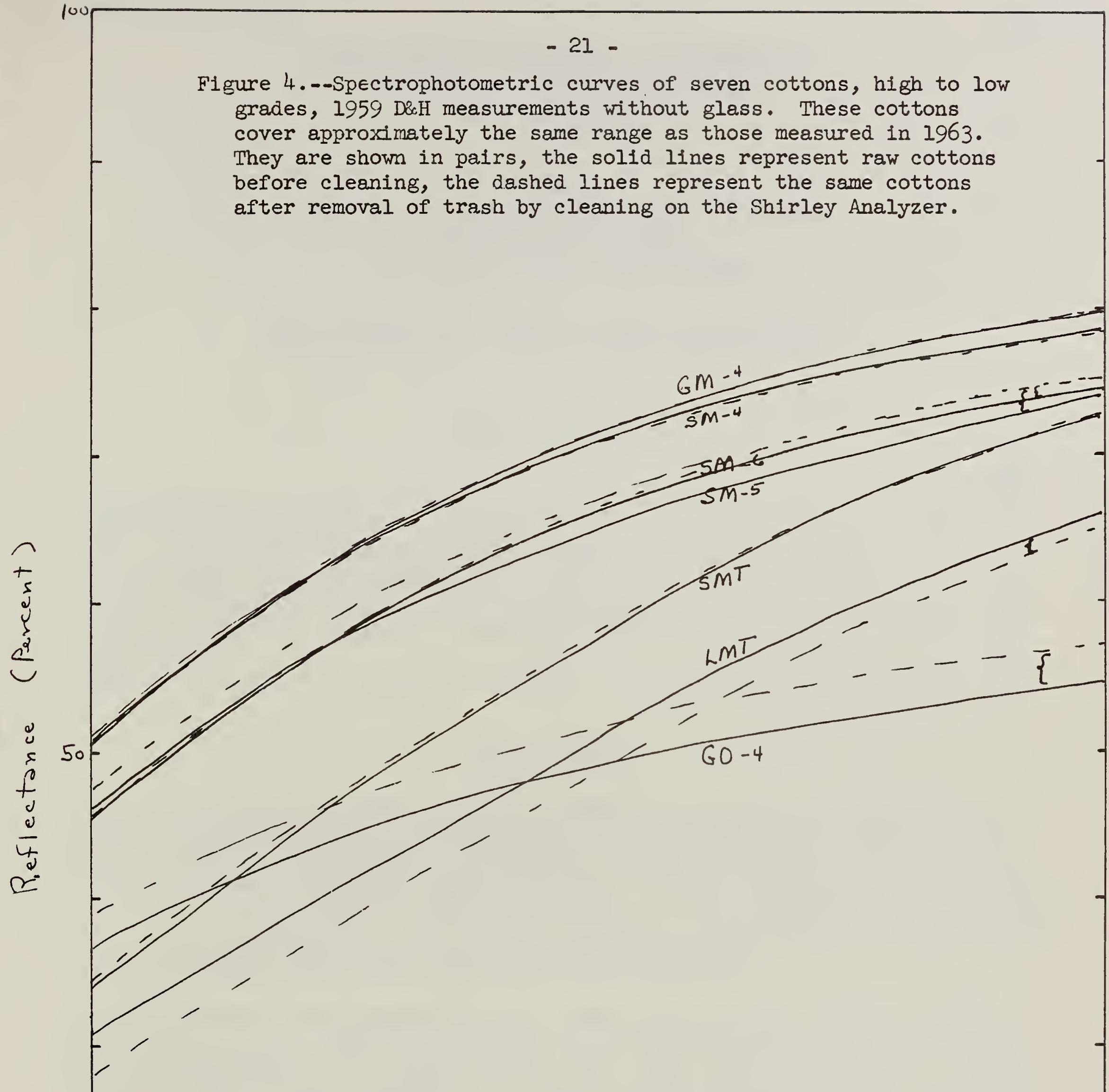


No.	Grade	From colorimeter Rd	From colorimeter +b	Calculated from spectrophotometer Rd	Calculated from spectrophotometer +b
1	GM	81.4	9.8	66.3	9.9
2	SM	78.6	9.7	63.6	9.8
3	SLM	71.0	8.0	58.7	8.0
4	GO	56.7	6.5	42.9	7.4
5	SMT	69.6	12.9	59.2	12.6
6	LMT	58.9	12.4	48.6	12.6

from DrH measurements Nov 1963 - thru plateglass

dn - 2/64

Figure 4.--Spectrophotometric curves of seven cottons, high to low grades, 1959 D&H measurements without glass. These cottons cover approximately the same range as those measured in 1963. They are shown in pairs, the solid lines represent raw cottons before cleaning, the dashed lines represent the same cottons after removal of trash by cleaning on the Shirley Analyzer.



Grade	Before Cleaning: from colorimeter R_d	$+b$	calculated from spectrophotometer R_d	$+b$	After cleaning: from colorimeter R_d	$+b$	calculated from spectrophotometer R_d	$+b$
GM-4	81.4	8.7	71.7	9.0	81.4	8.7	71.7	8.8
SM-4	79.8	8.7	71.2	8.9	79.8	8.7	71.1	8.8
SM-6	77.0	10.0	66.1	9.7	77.0	10.2	66.6	9.9
SLM-5	72.8	8.4	65.0	8.8	74.0	8.8	67.2	9.1
SMT	68.5	13.1	58.3	13.4	68.5	13.1	58.6	13.4
LMT	57.0	13.4	51.3	13.0	59.0	13.8	49.5	13.6
GO-4	57.0	6.1	48.8	6.5	59.4	6.4	51.7	6.8

from D+H measurements 1959- cotton wads, no glass

dm-2/64

0

400 500 600 700

λ in nm.

For Administrative Use

May 1964
Draft

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Washington, D. C.

Notes on A HISTORY OF UNITED STATES COTTON STANDARDS AND RELATED SUBJECTS
With an Annotated Bibliography

By Dorothy Nickerson* and Samuel R. Griffith**
Cotton Division, Standards and Testing Branch

Table of Contents

Introduction

In the early days when the production and use of cotton was limited, merchants used private types or actual samples in buying and selling cotton. The descriptive terms used to designate different qualities were numerous, and varied from one market area to another. As the production and utilization of cotton expanded, a need developed for a uniform method of describing quality as a basis for buying and selling cotton throughout the entire marketing channels from farmer to textile manufacturer.

Two designations which have been used since the earliest days to describe the quality of raw cotton are "grade" and "staple length." Grade relates to the appearance of the cotton—its color, leaf, and preparation. Staple length relates to the length of a typical portion of its fibers. For both of these quality aspects cotton standards have been developed and are made available by the United States Department of Agriculture.

This report is prepared as a reference summary of the literature on the history of the development of cotton standards of the United States that today are established under authority of the United States Cotton Standards Act and Cotton Futures Provisions of the Internal Revenue Code of 1954. It is particularly concerned with standards for grade and staple length of cotton and cotton linters. It also includes subjects closely

---

* Formerly Head, Standardization Section, since January 1964 with Market Quality Research Division, A.M.S.
** Cotton Marketing Specialist, Standardization Section.

related to the preparation, maintenance, and application of these standards. It is based on the publications listed in the annotated bibliography. The information in each section is drawn from publications cited in the margin at the beginning of each section. Many of these publications are long out of print, but the specialist or historian should be able to find them in specialized libraries or files. All but the DeLoach 1912 publication were available to the authors. Many of the more recent publications are available from the Agricultural Marketing Service, United States Department of Agriculture.

Early Terminology, Grades, and Standards

The earliest effort to develop standards for cotton is reported to have
8 originated in Liverpool, England. During the period from 1607 to 1780,
9 cotton was marketed by general merchants and was classified in England
11 primarily by its area of growth. For example, during this period cotton
45 usually came from the West Indies and the Levant. "Cyrus" and "Salonia"
51 were the names of two grades of West Indies (Sea Island) cotton.

59

109 The art of classing cotton is said to have been originated by Joshua
Holt, a Liverpool cotton broker, during the period 1775-1785.

As early as 1801, cotton brokers were using the term "Middling" in referring to quality designations of cotton. In 1808, Maury's Price Current classified Sea Island cotton in "fine," "good," "middling," "ordinary," and "stained," but referred to upland cottons only by names of producing countries.

By 1825, Liverpool brokers were describing upland cottons as "Good and Fine," "Good Fair," "Fair," "Middling," and "Ordinary."

In the early 1800's the United States, like England, classified cotton by reference to the region in which it was grown. For example, Sea Island cottons were called "Georgias," "Floridas," and "Island Crop Lots;" Upland cottons were called "Texas Blacklands," "Benders," "Rivers," "Peelers," "North Georgias," and "Canebrakers." These grade descriptions were not used, however, in all parts of the Cotton Belt. About 1860, in some areas cotton had only two classifications, "good" and "sorry."

In 1871, the New Orleans Cotton Exchange was organized. The grades of Good Middling, Strict Middling, Middling, Low Middling, Good Ordinary, Ordinary, Low Ordinary, and Inferior were established for use in this market.

In the United States one of the first attempts to reach agreement on uniform standards was made June 10, 1874, when the National Cotton Exchange (a group of American cotton exchange representatives) met in Augusta, Georgia, to consider adopting a "Standard American Classification." A committee of experts was selected to consider, agree upon, and make new standards which were then sent to cotton exchanges throughout the United States. These standards consisted of five grades: Good Middling, Middling, Low Middling, Good Ordinary, and Ordinary. They

were used for part of two seasons, but were then discontinued by all but the New York Cotton Exchange which used them until 1914. After the majority of United States cotton exchanges discontinued the use of these 1874 standards, there was a period of several years in which many diverse forms of standards were used by cotton exchanges. This made the marketing of cotton very disorderly and confusing. One of the main difficulties in establishing a uniform cotton standards system was the lack of adequate communication and transportation in those early days.

In 1907, the International Cotton Congress held a meeting in Atlanta, Georgia, which was attended by cotton growers, spinners, and manufacturers from Europe and America. This group passed a resolution favoring the adoption of new standards for grade and color. While no positive action was taken toward obtaining standards, this meeting stimulated public interest, which led eventually to standardization.

Proponents of standards maintained that among other things the establishment of a uniform standards system would eliminate price differences between different markets; provide a means for settling disputes; would make the farmer more cognizant of the value of his product and would thus put him in a better bargaining position; and in general be of great benefit to the cotton trade.

In 1908 a provision of the Appropriation Act for the United States Department of Agriculture authorized the Secretary of Agriculture to establish a standard for nine specified grades of cotton. A committee of nine men, prominent in various branches of the cotton trade, together with three experienced classers from the New York, New Orleans, and Dallas markets, prepared these standards. They were established in 1909, their use being entirely permissive. The nine grades were: Middling Fair, Strict Good Middling, Good Middling, Strict Middling, Middling, Strict Low Middling, Low Middling, Strict Good Ordinary, and Good Ordinary. These standards were not used extensively.

In the years between 1833 and 1913, the Liverpool Cotton Association began using three sets of standards that represented Upland, Gulf and Texas cotton, respectively, known as the Liverpool Standards. No one knows their exact origin, but it is thought that they gradually evolved from use of private types.

In June 1913, a group of cotton men representing the Liverpool, Le Havre, Bremen, and American exchanges and spinners' associations met in Liverpool. During the conference the so-called International Standards, a modification of the pre-existing Liverpool Standards for Upland Cotton, were agreed upon. These standards were adopted by Liverpool and the Bremen and Le Havre exchanges, but Liverpool continued use of its own standards for Gulf and Texas cottons. There was some misunderstanding regarding the growths represented, and the Americans did not bind themselves to acceptance. Thus this attempt to establish universal standards failed. (As a matter of historical interest, color measurements were made and reported[25] in 1954 for several of these old standards.)

Official Standards Authorized Under Cotton Futures Act, 1914

The United States Cotton Futures Act of August 18, 1914, section nine,
7 authorized the Secretary of Agriculture to establish standards as a
45-51 means of determining value of cotton and for determining grade, staple length and strength, and other qualities and properties. The Secretary was also authorized to change the standards from time to time as might be needed, after notice of at least 1 year.

Experts from the New York and New Orleans Cotton Exchanges assisted the United States Department of Agriculture staff in developing new grade standards, using the 1909 official standards and the International (Liverpool) Standards as guides.

A major requirement in preparing the standards was to secure "comprehensive standards for cotton of American growth which would be adapted to the needs of the trade in the United States and at the same time might be suitable for adoption as international or universal standards for American cotton."[51] It was determined that cotton, in grade boxes of 12 samples each, would be selected to represent all growths throughout the Cotton Belt. A numerical system 1 to 12 was set up to insure that the grade characteristics of each sample or "biscuit" would correspond in every box of the same grade. Photographs were placed in each box cover to verify the authenticity of trash content.

The resulting "Official Cotton Standards of the United States" were ordered by the Act to be "established and promulgated" for nine grades. A set of samples representing nine White grades—Middling Fair, Strict Good Middling, Good Middling, Strict Middling, Middling, Strict Low Middling, Low Middling, Strict Good Ordinary, and Good Ordinary—was promulgated by the Secretary of Agriculture on December 15, 1914. Each grade was marked with its name and designated "Original official cotton standards of the United States." It was ordered that these standards replace those established in 1909.

Under the Cotton Futures Act, exchanges buying and selling cotton for futures delivery were required to use these official standards in transactions after February 18, 1915. However, most major cotton exchanges and spot markets in the United States voluntarily adopted and used these standards as a basis on which to furnish daily quotations. Conferences of Department representatives (W. R. Meadows and W. P. Barbot) in November and December 1914, with Liverpool, Bremen, and Le Havre representatives, very nearly succeeded in gaining adoption of these standards for universal use. It was even agreed that if adopted they could be known in Europe as "Washington-Liverpool Standards." Partly because action could not be concluded before December 15, 1914—the necessary date for U. S. promulgation—European firms did not adopt them, but continued to use the International or Liverpool Standards until 1916 when new Liverpool Standards—which included Upland, Gulf, and Texas growths—became effective. These Liverpool Standards were very similar to the Official Cotton Standards of the United States.

In a 1915 address to the Alabama State Bar Association, the Solicitor of the United States Department of Agriculture listed the following shortcomings of marketing practices then in existence that the Cotton Futures Act was designed to correct:

(1) Multiplicity of standards of classification used in the conduct of the cotton business in various parts of the country.

(2) A system of so-called fixed differences between values of grades used in the settlement of exchange contracts.

(3) The delivery upon exchange contracts of low-grade or inferior cotton, which the majority of spinners could not use in their factories.

(4) The failure of tenderers of cotton on exchange contracts to show the grades to be delivered.

(5) The so-called pro-forma delivery practice, under which long periods of time often elapsed before the person obligated by an exchange contract to receive cotton was informed of the grades, although he had been forced through the exchange rules to pay for it at the time fixed for delivery, by the opposing party to the contract.

The Solicitor's address summarized the 1914 Cotton Futures Act by referring to a number of the provisions that govern the marketing of cotton.

Standards for colored cotton were established by order of the Secre-
53 tary of Agriculture on January 28, 1916. At that time the following
11 grades were added to the 9 grades of White standards established in 1914: 5 grades of Yellow Tinged, Good Middling through Low Middling; 3 grades of Yellow Stained, Good Middling through Middling; and 3 grades of Blue Stained cottons, Good Middling through Middling. This made a total of 20 grade standards represented in physical form.

The Cotton Futures Act was re-enacted August 11, 1916, effective
54 September 1, 1916 (after the original 1914 Act was declared uncon-
55 stitutional). Under its authority the Official Cotton Standards of
the United States established in 1914 were, on August 12, 1916, re-established and promulgated under the act of August 11, 1916. These included standards for White grades and grades of Yellow Tinged, Yellow Stained, and Blue Stained cottons.

Safeguarding and maintaining standards without change was a problem
19 recognized by the United States Department of Agriculture from the
50 beginning of its standards work. Experiments conducted on sets of
51 these early standards included storage in vacuum containers, the
purpose being to find a method of holding any color change in the cotton to a minimum while in storage. Vacuum storage was not successful. Color measurements and classification comparisons made in 1931 of 1923 and 1924 vacuum-packed cottons showed that about as much color change occurred in vacuum-packed as in non-vacuum-packed samples.

In 1916, the United States Department of Agriculture reported many of the details of its method of preparing standards. This included a description of its facilities, and its early specifications for providing classing rooms with skylighting and humidifiers. Even in these very early days, as many as 200 to 300 bales of cotton selected from all parts of the Cotton Belt were kept on hand for use in making standards.

Official standards for American Egyptian and Sea Island cottons were estab-
56 lished in 1918, effective October 25. By that time the production of American Egyptian and Sea Island cottons had increased to the point that there became a need for official standards.

Prior to 1918, the only standards in existence for American Egyptian cotton were the permissive standards established in 1913 for the Yuma variety. However, by 1918 the Yuma variety was largely replaced in production by the Pima variety. Therefore, it became necessary to prepare Pima standards. The new grades established were based on "types" of the Pima variety. The grade names for these types were Fancy, Extra, Choice, Standard, and Medium. However, in the new official grades, the names were replaced by numbers, 1 for Fancy, 2 for Extra, 3 for Choice, 4 for Standard, 5 for Medium, and "below grade 5," with intermediate grades that were identified by "1/2." Standards for grades 1 through 5 were represented by samples in suitably marked containers. The intermediate 1/2 grades and "below grade" standards were descriptive.

Grades for Sea Island, prior to 1918, were Fancy, Extra Choice, Choice, Extra Fine, Fine, and Medium Fine. When Official Standards for Sea Island cotton were established, some of the merchants' private types were used for making up United States Department of Agriculture grade boxes. Sea Island grades were numbered 1 through 6, and "below grade 6." Split grades were designated by "1/2." Standards for grades 1 through 6 were represented by samples in suitably marked containers; the remainder of the grades were descriptive.

Standards for length of staple were established in 1918. For several
56 years, the United States Department of Agriculture had been making investigations toward the possibility of establishing standards for staple length. A poll was taken of mill owners, merchants, buyers, and shippers to discover whether they wished to have the government establish staple standards. Approximately 70 percent of the group polled favored making such standards.

Various members of the cotton industry were asked to furnish the United States Department of Agriculture with private types representing the different staple lengths. Four hundred and eight samples submitted to the United States Department of Agriculture were examined by nine experts.

Official staple standards were promulgated effective October 25, 1918. The order contained the following five sections:

(1) The length of staple of any cotton was defined as "the normal length by measurement without regard to quality or value, of a typical portion of its fibers under a relative humidity of the atmosphere 65 per centum and a temperature of 70 degrees, Fahrenheit."

(2) Lengths were established from 3/4" to 1 inch in 1/16" graduations; 1 inch to 1-3/4" in 1/32" graduations; and below 3/4".

(3) Nine lengths were represented by physical types: 3/4", 7/8", 1", 1-1/8", 1-1/4", 1-3/8", 1-1/2", 1-5/8", 1-3/4".

(4) Cotton which is more than three-fourths of an inch in length of staple but is not exactly one of the measurements specified above, shall be designated by that one of such measurements which comes nearest under its true measurement.

(5) Whenever the length of staple of cotton taken from one part of a bale is different from that taken from another part of the same bale, the length of staple of the cotton in such bale shall be that of the part which is the shorter.

At the time that staple standards were established, photographs were published of the successive motions involved in a recommended standard method for pulling staple.

57 Regulations of Cotton Futures Act were amended March 4, 1919.

58 Revised Regulations of September 15, 1919, for Cotton Warehouses under the United States Warehouse Act.

Regulation 8 concerns cotton classification, and contains definitions of irregularities or defects relating to cotton packaging or quality.

60 Revision of official grade standards for both American upland and American Egyptian cotton occurred July 26, 1922, effective August 1, 1923.

Because there was too large a proportion of creamy cotton in the old standards for grades of Middling Fair and Strict Middling upland cotton in relation to lower boxes, these grades were made less "creamy" and a little more leafy. Because recent boll weevil damage to cotton had caused the greater part of the crop to show slight discoloration from boll weevil spots, a small amount of color was added to the white upland standards to take care of this. The new standards provided for the addition of 12 descriptive grades—5 Spotted, 3 Light Stained, and Strict Good Middling Yellow Tinged—that would designate cottons intermediate in color between Blue Stained and White, between White and Yellow Tinged, between Yellow Tinged and Yellow Stained cottons, and add Strict Good Middling to the group of Yellow Tinged grades. This made a total of 32 grade standards for American upland cotton—20 represented in physical form, and 12 descriptive. A general section of the order establishing these standards provided, for the first time, a rule for averaging of factors that determine grade and color.

Following a general policy of employing numbers for all commodities for which standards are established within the then Bureau of Agricultural Economics, a numerical system was applied to all official grade standards, assigning No. 1 to the highest commercial grade and succeeding numbers to lower grades in order. For example, the numerical grade for Middling Fair was 1, Strict Good Middling 2, Good Middling 3, Strict Middling 4, Middling 5, Strict Low Middling 6, Low Middling 7, Strict Good Ordinary 8, and Good Ordinary 9. Use of the full grade nomenclature was continued in addition to numerical designations. The relation of the physical and descriptive grades, and their numerical designations were illustrated in the form of a table of "Grades and Colors of the Official Cotton Standards for American Upland Cotton."

Revised regulations, July 18, 1922, effective August 1, 1922, limited the validity of practical forms of the grade standards distributed after August 1, 1922, to 18 months following the date of their certification.

Revised standards were established for grades and colors of American Egyptian cottons on July 26, 1922, effective August 1, 1923, to replace those established in 1918 which had contained a certain amount of reddish color caused by anthracnose, a fungus disease which attacked the growing plant in Arizona. This color had been so reduced in the intervening years that the standards no longer represented the crop. New standards promulgated in 1922 were prepared to represent cotton grown under improved conditions, but contained four samples in each box from the old standards. Standards for grades 1 to 5 were established in physical form, with intermediate 1/2 grades and "Below Grade No. 5," made descriptive.

United States Cotton Standards Act, 1923

The following provisions are summarized from the 14 sections of the United
36 States Cotton Standards Act passed March 4, 1923:

61

62 Sec. 2. It shall be unlawful to indicate for any cotton a grade or
63 other class which is of or within the official cotton stand-
65 ards of the United States then in effect by a name description, or designation not used in these standards. One exception to this rule would be actual samples or private types not used in evasion of or substitution for the official standards.

Sec. 3. The United States Department of Agriculture may license persons to classify cotton and certificate its grade or other class in accordance with official cotton standards.

Sec. 4. The owner or custodian of the cotton may submit samples to the United States Department of Agriculture for determining the classification.

Sec. 6. The Secretary of Agriculture is authorized to establish standards for the classification of cotton by which its quality or value may be judged or determined for commercial purposes. The official standards effective August 1, 1923 under the United States Cotton Futures Act shall be the official cotton standards unless and until changed or replaced under this act.

Passage of the Cotton Standards Act raised questions regarding American export trade. The law required discontinuance of use of all foreign standards in this country in conflict with the official standards of the United States. At the time, cotton exchanges of Europe whose committees had always arbitrated disputes between American shippers and European receivers, did not recognize the official standards. Therefore the Department promptly lent its efforts to the solution of this difficulty.

In April, May, June, and July of 1923, a series of conferences were held in Washington with representatives of producers, shippers, and spinners organizations. Public hearings were held in 13 of the principal markets in the United States. One of the early problems for exporters was to find in the official staple standards equivalents for millimeter staple descriptions.

The conference of June 11-12, 1923, perhaps the most important one, was called in response to a request by the Liverpool Cotton Association, with several overseas delegates present. The greatest difficulty concerned the Liverpool objection to the official staple length standards, and the unwillingness of all principal European exchanges to relinquish their authority to arbitrate disputes arising out of shipments from the United States.

As a result of this conference the Department and representatives of the American cotton industry recognized the difficulties of the European delegates in accepting the official standards for length of staple, and proposed that "in case the European associations adopted the official cotton standards of the United States for grade and color as universal standards the Secretary of Agriculture will take such action as may be necessary" to vest in members of the European exchanges authority to determine the final classification for grade and color in accord with those standards. The representative of the Le Havre and Belgian associations accepted the proposal at once, and the Liverpool exchange, after recalling its delegates for discussion, cabled its acceptance on June 27 but made objection to the color of certain bales in the Middling and Strict Middling boxes. The two Manchester associations took favorable action on July 2 and 9. Bremen cabled its acceptance "on principle" on July 22.

As a consequence of Liverpool's criticism, and the expressed willingness of American shippers to consider a revision of standards, a conference was called for July 17, 1923 in Washington. After considerable deliberation the conference agreed unanimously on the change of the No. 12 sample in the Good Middling and Strict Middling boxes, in Middling to the removal of Nos. 4 and 6 and addition of new bales similar to 3 and 7, and to substitution of a new box prepared by the Americans for Strict Low Middling, a box of a little better general color and slightly less spotted than the old box. It was agreed that while there was slightly better average color, the new bales carried enough more leaf to offset this. The Department reported that these revisions caused no perceptible change in grade value.

On July 30, 1923, effective August 1, 1924, the revised standards for white and colored grades were established in accord with Section 6 of the Cotton Standards Act, replacing standards established on July 26,

1922, the only changes being in the four grades noted. The plan of standardization and the relation of descriptive grades to those represented in physical form remained as described in the revision of July 26, 1922, which included the averaging rule. The order that established these standards as "Official Cotton Standards of the United States for Grades and Colors of American Upland Cotton" contained a provision that "inasmuch as they had been agreed upon and accepted by all the leading European exchanges, they may also be termed and referred to as Universal Standards for American Cotton."

Regulations issued on July 21, 1923, under the Cotton Standards Act provided for informal classification on a Form A memorandum, or a more formal classification on Form B or C. The classification services included reviews and appeals. The regulations also provided that members of associations or exchanges located in a foreign country that adopt the United States official cotton standards as a basis for its transactions and contracts for American upland cotton, may be appointed as cotton examiner under the act, and function as boards of cotton examiners of the Department of Agriculture.

<u>Universal Standards Agreement</u>. The discussions that led to the estab-
62 lishment of Universal Standards brought the cotton trade of the world
63 into a harmonious working relationship. The results were crystallized in a memorandum of agreement submitted to the European organizations by Department representatives (L. S. Tenny and A. W. Palmer) in a series of conferences held in Europe. The Liverpool Cotton Association signed the agreement on August 8, 1923, and signatures of the other eight European participants were obtained in the following several weeks. These included: Manchester Cotton Association, Ltd., Aug. 9, 1923; Syndicat du Commerce des Cotons au Havre, Aug. 21, 1923; Bremer Baumwollbörse, Aug. 16, 1923; Associazione Cotoniera Italiana, Nov. 12, 1923; Association Cotoniere de Belgique, Nov. 22, 1923; Centro Algodonero de Barcelona, Aug. 24, 1923; Vereeniging voor den Katoenhandel te Rotterdam, Aug. 17, 1923; Federation of Master Cotton Spinners' Associations, Ltd. of England, Sept. 7, 1923. The Marché de Coton Belge, of Ghent, applied to be made a party, but since the documents signed by the other exchanges did not include the Marché, a separate agreement was drawn up.

The agreement provided, among other things, that:

(1) The associations would use the Universal Standards as a basis for all contracts in which grades are specified for purchase and sale of American cotton.

(2) The original standards were to be kept by the United States Department of Agriculture at Washington, D. C., and no copies would be used except those prepared by the Department.

(3) No changes in standards would be made without holding meetings for delegates from the various cotton exchanges for the purpose of considering the proposed changes. At such meetings the voting power of 100 would be distributed

so that 50 votes would be cast by representatives of the associations according to apportionment they may themselves have agreed on and 50 votes by the United States.

(4) Upon written request by associations or groups of associations representing at least 15 votes, a meeting would be called to consider proposed changes.

(5) The Department of Agriculture would appoint members of appeal committees of the respective association as cotton examiners authorized to determine the classification by comparison with the Universal Standards, and issue certificates showing these determinations, which, by regulation, would be final.

(6) Provision for withdrawal of any party to the agreement.

A supplemental agrement made a year later between the United States Department of Agriculture and the European cotton associations contained provisions for holding annual conferences, beginning in 1925. This was for the purpose of examining and approving sets of copies of Universal Standards for the use of the United States and the associations, for it was recognized that in spite of the greatest care and most favorable conditions of storage, the physical appearance of the original samples constituting the Universal Standards might change in storage.

It provided that each association might be represented by one or two experts in the classification of American upland cotton, the United States to be represented by as many experts as the number representing the European associations. Special provisions were to be made for the protection, storage, and preservation of copies of the standards furnished the associations as well as those retained by the United States Department of Agriculture in Washington.

The sole purpose of the meetings provided for in the supplementary agreement was the examination and approval of copies of the original Universal Standards. It was expressly provided that such copies were not to depart from the original Universal Standards as and when they were established.

The action of the Department in entering into agreements with the European associations was sustained by the Solicitor of the Department and later by the Acting Attorney General of the United States in a formal opinion dated May 11, 1925.

American Egyptian grade standards of 1918 were re-established on
63 July 26, 1924, to become effective on August 1, 1925. The improvement made by the 1922 revision of these standards had been so slight that the standards were not in keeping with actual crop conditions, and producers, as well as shippers and spinners, requested that the original grades be re-established. Consequently the original standards for grades of American Egyptian cotton as they were established

in 1918 again became effective. Grades 1 through 5 were represented by samples, the intermediate 1/2 grades, and "below grade," were descriptive.

Sea Island standards were discontinued by an order dated January 22,
63 1925, since the crop had become too small to justify preparation of
79 official standards. Owing to ravages of the boll weevil, Sea Island
cotton had virtually disappeared from the United States crop.

1925 Universal Cotton Standards Conference. The first conference under
63 the supplementary agreement was held March 1925, in Washington, D. C.
for the purpose of examining and approving copies of the original standards. At that meeting arrangements were made to hold a meeting under the principal agreement, on May 20, 1925, in London. The Department was represented by Dr. Henry C. Taylor, H. C. Slade, and Wm. I. Holt. At the London meeting the supplemental agreement was amended to provide for biennial meetings, beginning in 1927, and provisions were slightly modified for handling and comparison of reserve sets. For legal reasons a few changes were made in the original agreement. All actions were by unanimous vote.

Staple standards amended, 1925. The official standards for length of
63 staple effective since October 25, 1918, amended August 4, 1921, to
include lengths 1-1/16, 1-3/16, and 1-5/16 inches in physical types, were further amended September 18, 1924 to include the length 15/16 inches as a physical type. On July 31, 1925, effective August 1, 1926, the staple standards for both American upland and American Egyptian cottons were amended. This amendment provided for 17 physical types of American upland cotton, and 4 for American Egyptian. The complete list of grade standards is shown on table 1.

Linters standards established, 1925 and 1927. Linters, which in early
15 days were considered a nuisance by cottonseed oil processors, came
64 into increasing demand as new uses for it were created. As these uses
67 increased, the importance of producing linters free from foreign matter
became evident. The demand for linters gradually took this product out of the waste class, and gave it the character of a special industry. This led to a request in 1924 by the Interstate Cottonseed Crushers' Association for the government to establish standard grades for linters. On July 7, 1925, under authority of the Cotton Standards Act, grade standards for linters were established, effective August 1, 1926. The grades established were: 1 through 7, Hull Fiber (lower than grade 7), and Compound Grades.

At a later conference, October 6, 1927, representatives of the linters industry requested that the factor of color be included in standards for linters. This was done by order of the Secretary of Agriculture on October 31, 1927, to be effective 1 year later, permissive until that date.

Extra White standards established, 1926. By 1926 farmers in the South-
67 west were growing increasing amounts of irrigated cotton. This cotton
was whiter in color than most of the rain-grown cotton represented in the color range of the existing grade standards, and could not therefore

be readily classified against existing standards. The United States Department of Agriculture was requested to make provision for standardization of cottons from that region. After considerable thought it was concluded that the most practical way of meeting the situation was to add to the existing standards five boxes for Extra White cottons. Consequently, on March 3, 1926, effective August 1, 1927, official standards for Extra White cotton, Grade No. 3, Good Middling Extra White, through No. 7, Low Middling Extra White, were established in physical form under authority of the Cotton Standards Act. On August 30, 1927, the same standards were established under the Cotton Futures Act, effective September 1, 1928.

<u>London Conference on Staple Standards, 1926</u>. Following requests from
67 European and American cotton associations for adoption of Universal Standards for staple length, the Secretary of Agriculture invited representatives of the European exchanges to a conference on August 11, 1926, in London, England. At that meeting, L. S. Tenny, for the Department, reviewed the circumstances, and invited open discussion. A basis of agreement was not found on the question of universal staple standards. The United States Department of Agriculture expressed its readiness and willingness to deal with this question. Meanwhile the official standards for length of staple continue to be the required basis for transactions in American cotton sold on standard description in interstate and foreign commerce.

Table 1.--Official cotton standards of the United States for length of staple. Checks indicate physical types, stars represent descriptive standards

Lengths (inches)	1918	1921	1924	1925 AU	1925 AE	Lengths (inches)	1918	1921	1925 AU	1925 AE
Below 3/4	*					1-11/32	*		√	
3/4	√			√		1-3/8	√		√	
13/16	*					1-13/32	*			
7/8	√			√		1-7/16	*			
29/32						1-15/32	*			
15/16	*		√	√		1-1/2	√		√	√
31/32						1-17/32	*			
1	√			√		1-9/16	*			√
1-1/32	*			√		1-19/32	*			•
1-1/16	*	√		√		1-5/8	√			√
1-3/32	*			√		1-21/32	*			
1-1/8	√			√		1-11/16	*			
1-5/32	*			√		1-23/32	*			
1-3/16	*	√		√		1-3/4	√			√
1-7/32	*			√		and upwards in 32nds	*			
1-1/4	√			√						
1-9/32	*			√						
1-5/16	*	√		√						

1927 Universal Cotton Standards Conference. The second regular biennial
67 Universal Cotton Standards Conference provided for in agreements between the United States Department of Agriculture and the nine leading cotton exchanges and associations of Europe was held in Washington, D. C., March 14, 1927. At this conference 60 full sets of copies of the Universal Standards (White, Yellow Tinged, Yellow Stained, and Blue Stained grades, a total of 1,200 boxes) were inspected and approved.

66 Regulations. Following this conference, revised regulations were pub-
68 lished under both Cotton Futures (May 15, 1927) and Cotton Standards Acts (October 1, 1925).

Staple standards revised, 1928. Length designations 29/32 and 31/32
69 were added to the list of staple standards by amendment of November 16, 1928, effective November 16, 1929. No arrangements were made for issuing staple types of these added lengths.

Revision of American Egyptian and Extra White standards, 1929. On
69 March 14, prior to the 1929 Universal Cotton Standards Conference with European groups, representatives of American associations of growers, merchants, and manufacturers met with the Department to consider suggested revisions in American Egyptian standards which no longer were representative of cotton produced in recent crops, to examine key copies of standards for Extra White, and to discuss informally several proposals scheduled for discussion at the conference with the European associations. Revised standards as exhibited in tentative form for grades of American Egyptian cottons, excluding half grades, and for grades of Extra White upland cottons, were accepted by unanimous agreement of those present, and thereafter were established by the Secretary of Agriculture, effective August 1, 1930.

1929 Universal Cotton Standards Conference. The third meeting of the
69 Universal Cotton Standards Conference was convened in Washington, D.C., March 16, 1929. Sixty-five full sets of copies of the Universal Standards for American cotton were inspected and approved, a total of 1,300 boxes.

On March 19, at a meeting held under the principal agreement, in accord with prior notification the following proposals were discussed:

(1) To set up standards boxes for Spotted grades;

(2) To set up standard grade descriptions of "Light Yellow Tinged" between Spotted and Yellow Tinged cotton;

(3) To prepare types to represent the preparation factor for three grades of long staple cotton.

The second proposal was made because the tentative boxes available for spotted cotton did not cover the entire range of color between White and Yellow Tinged. However, the European delegates were not yet ready to accept Spotted standards, therefore no definite conclusion was reached on either of the first two proposals.

In regard to the third proposal, the desirability of having preparation standards was generally accepted in principle. It was agreed that tentative standards be prepared for trial use in the next two years, so that their general usefulness could be demonstrated before making them a part of the next conference. As a consequence, tentative standards for the preparation of long staple cottons were established by order of the Secretary on May 20, 1929.

The European delegates unanimously proposed to make Blue Stained and Yellow Stained standards inactive, and not to submit them for passing at this conference. A representative of the Bureau replied that it might be possible to exclude them from consideration at subsequent conferences.

The question of Japanese participation in the Universal Standards conferences was raised. European delegates indicated, as they had in prior correspondence, that while they had no objection to a separate Department agreement with Japan, they did not agree to a change in the present agreement with the European exchanges.

Delegates to the conference urged improvement in present ginning methods "which are said to result in deterioration in the quality of spinnable cotton." They adopted a resolution condemning the tendency to hurry the work through the gins.

Amendment to American Egyptian standards, 1930. Half grades for
73 describing American Egyptian cottons intermediate between standards
established for grades 1 to 5 were re-established by amendment of
July 3, 1930 to the 1929 order which had excluded them.

1931 Universal Cotton Standards Conference. The fourth Universal
73 Cotton Standards Conference opened in Washington, D. C., on May 9,
1931. Sixty-five full sets of standards and additional copies of
Strict Middling to Low Middling grades were approved, a total of 1,385
boxes. Unanimous approval was lacking for a proposal that Blue and
Yellow Stained standards be transferred to inactive standards, and be
prepared by Department experts. Therefore the boxes representing
these grades were submitted for approval along with the others.

At a meeting held under the principal agreement on May 12 a resolution from the Liverpool association stated that they were not prepared to adopt the preparation types received following discussion at the previous conference. However, while they were unwilling to recommend formal adoption of the tentative preparation standards, they were willing to have them used in arbitrations.

American manufacturers, by resolution, requested the Department to show the proper grade factors for color and trash in each preparation box.

During general discussion the problem was raised of unsatisfactory baling and moisture in American cotton, and of oil damaged cotton and cotton containing jute fibers. In reply, it was pointed out that the Department of Agriculture had no legal authority to exercise regulatory control over the matters referred to. However, attention was called to the recent establishment of a ginning laboratory at Stoneville, Miss.

70 Revised Regulations of the Secretary of Agriculture were issued May 1931
71 under both the United States Cotton Futures Act and the United States
Cotton Standards Act.

1933 Universal Cotton Standards Conference. At the fifth Universal Cot-
72 ton Standards Conference, held in Washington, D. C., March 16, 1933, 65
73 full sets, plus additional boxes of White grades, were inspected and
approved as copies of the Universal Standards, a total of 1,470 boxes.

Under the principal agreement several items were considered: first, a written request from Liverpool, agreed to by several European associations, that new Universal Standards be prepared for the grades Good Middling and Strict Good Middling in order that the excess amount of buttery or creamy color in them might be reduced.

The Department agreed with this request, but thought additional changes should be considered to eliminate minor inconsistencies and to bring grades into better alignment with present crops. American interests suggested the need for elimination of boxes for Blue and Yellow Stained grades, narrowing the color range for existing standards for Spotted cotton, and making provision for cotton brighter than present boxes. Meanwhile, European groups withdrew the request for a change in SGM and GM boxes. Nevertheless, the Department announced that a comprehensive study would be made of the standards situation to determine whether, and to what extent, revisions might be desirable, results to be presented before further action would be taken.

A request by the European associations to extend the period of conferences from 2- to 3-year intervals was not adopted, since Department and American industry representatives felt this impracticable at this time.

Attention of delegates was called to technological work at the Stoneville ginning laboratory.

Some European delegates voiced objection to use of sisal bagging asserting that sisal fibers damage cotton and that sisal bagging had no resale value.

Revision of Extra White standards, 1933. Effective August 10, 1933,
73 Extra White standards for upland cotton were revised, their use to be
permissive until that date. The new standards included bales from each
major section of the Cotton Belt, and applied to any cotton of American
growth which corresponded to them in color.

73 Amendment to staple standards, 1933. Effective August 1, 1933, the
United States Staple Standards order was amended to provide for physical
types for 13/16", 29/32", and 31/32" staple lengths.

Revision of standards for grades of American upland cotton, 1935. Fol-
74 lowing the 1933 Universal Standards Conference, the United States
76 Department of Agriculture made thorough surveys that included an exam-
ination of data already available, and of crop and market surveys, both
of cottons currently produced and those available in the various markets.

Color measurements of the 1934 crop survey showed: 1, a definite concentration of cottons in grades 4 to 6 of White and Extra White, with the heaviest concentration toward Extra White; 2, small proportions of very high or very low grades; 3, a lack of yellow and blue stained colors. To find these extreme colors, a survey was made of cottons available in several of the important spot markets, but it was virtually impossible to find even a few bales of some of these colors. It was noted also that very little cotton in these markets was classed Extra White, although by color measurement and by Appeal Board classification many of these samples graded Extra White. In other words, much of the cotton called White was considerably whiter than cottons in the White standards.

It was apparent that current standards needed a number of revisions and a set was therefore prepared that contained the following changes:

(1) Blue Stained grades eliminated;

(2) Yellow Stained grades made descriptive;

(3) Standards for White cottons shifted to include whiter color;

(4) The more creamy samples in higher grades eliminated (not enough could be found to make standards);

(5) Grade No. 1, Middling Fair, made descriptive;

(6) Extra White grades made descriptive, and increased in number from five to seven;

(7) Deeper colors eliminated in Tinged grades;

(8) Much of light tinged cotton excluded from descriptive standards for Spotted (as a result of changes in White and Tinged standards);

(9) No. 2, SGM Yellow Tinged, eliminated.

This revision reduced the number of grades from 37 to 32, and the number of boxes from 25 to 13. The new standards included grades for White, Extra White, Gray, Spotted, Tinged, and Yellow Stained classifications for color.

The revised boxes were exhibited July 11, 1935 in Washington to representatives of American cotton associations, and on July 25 and 26 at Le Havre, France (by C. L. Finch and H. C. Slade) to representatives of the European organizations that were parties to the Universal Cotton Standards agreements. On August 19 in Washington they were shown again to American representatives, with certain modifications suggested and perfected at the Le Havre meeting.

Formal promulgation of revised standards based on these boxes was issued August 20, 1935, effective August 20, 1936. Prior to this date standards for Extra White had not been a part of the Universal Standards.

1936 Universal Cotton Standards Conference. By mutual agreement the sixth
75 Universal Cotton Standards Conference, which normally would have been held
79 in March 1935, was postponed to March 1936. The meeting was held in
Washington, D. C., for the purpose of examining and approving key sets of copies of the original official standards for grade of American upland cotton, as established to be effective August 20, 1936.

Agreement was reached that hereafter conferences be held at 3-year intervals.

77 Revised regulations were issued August 1936 under both the United States
78 Cotton Futures Act and the United States Cotton Standards Act.

Sea Island standards re-established, 1938. Official standards for Sea
79 Island growths originally promulgated in 1918 were discontinued in 1925.
By 1938 production of Sea Island cotton had increased enough so that standards were again needed. Following a meeting of trade representatives in Washington July 30, 1938, new standards were established by order of August 10, 1938, effective August 10, 1939, for six grades, Nos. 1 to 6, to be represented by samples, with descriptive 1/2 grades intermediate between these, and a descriptive grade, "Below Grade 6." In a separate promulgation order, staple standards for Sea Island were established in physical form, effective August 10, 1939, for four lengths: 1-1/2, 1-9/16, 1-5/8, and 1-3/4 inches.

1939 Universal Cotton Standards Conference. The seventh Universal Cotton
79 Standards Conference convened on March 13, 1939 in Washington, D. C. Key
sets of standards were examined and approved to represent the original standards established August 20, 1935.

A request received from the Gdynia Cotton Association for admission to the Universal Cotton Standards Agreements was favorably received. (Completion of negotiations was prevented by the European war and invasion of Poland.) Consideration was requested for some arrangement by which meetings under Supplemental Agreement A might be dispensed with and separate meetings arranged at 3-year intervals with American and Japanese organizations in Washington, and with representatives of the European associations at one of the European markets, with a limited number of key sets taken for examination by the European representatives. There seemed to be general agreement with this proposal, and it was left that at some future time it might be taken up officially with the signatories.

Supplemental Agreement B, which provides for Japanese participation, was presented and later signed by European and Japanese associations, and by the Secretary of Agriculture (January 31, 1939).

American Egyptian standards, 1940 revision. By 1940, growths of American
79 Egyptian cotton had changed so much since the 1929 revision of standards
that it became necessary to make further revisions. Acreage planted to the SxP variety (a cross between Egyptian Sakellaridis and Pima) had increased to the point where there was a need for standards to match that variety. Consequently, standards approved at a meeting in Washington on March 4, 1940, were established, nine boxes each for American Egyptian Pima cotton, and for American Egyptian SxP. Grades were numbered 1 to 5, with 1/2 grades between, and a descriptive grade for "Below Grade No. 5." These standards were established March 19, 1940, effective March 20, 1941.

Staple standards, in effect July 1942. A summary of staple standards in
79 effect July 1942, from "below 3/4 inch" to "1-3/4 inches and above" in 32nds inches is contained in a Public Notice of July 1942 (p. 16). Seventeen standards in physical form are included for American upland, 3/4 inch to 1-1/2 inches; four for American Egyptian, 1-1/2, 1-9/16, 1-5/8, and 1-3/4 inches; and reference is made to Sea Island standards, established effective August 10, 1939.

Staple standards, A.E., 1943. Effective August 10, 1943, physical types
100* were promulgated for American Egyptian cotton for staple lengths of 1-3/8 and 1-7/16 inches.

1946 Universal Cotton Standards Conference. The eighth Universal Cotton
80 Standards Conference was held in Washington, D. C., April 1946. Due to
81 World War II, this was the first conference held since 1939, and during this 7-year period, copies of the 1935 standards made and stored since 1939 had changed considerably. Visual observations by the classers on this point were confirmed by color measurements made of the boxes in 1935 and 1939. Therefore, a new set of boxes was made up, its purpose being to match the original 1935 standards as closely as possible. Because the difference in appearance was so great between key sets stored since 1939 and the new set of boxes, delegates were asked to come to this conference prepared to consider the new boxes as revised standards.

There was criticism from spokesmen for the United States cotton manufacturers' group that the new boxes "illustrated less desirable color and lower values than the old standards." They were unwilling to approve the new boxes, and withdrew before the conclusion of the conference. However, the proposed revised standards, supported by color measurement data, were approved by the majority of all other groups present. It was agreed that Strict Low Middling Gray be added as a descriptive grade. Revised standards were established by order of the Secretary of Agriculture on April 30, 1946, effective August 1, 1947. These standards were to be known as Official Standards of the United States, and as Universal Standards for American Cotton, a total of 33 grades, 13 in physical form, 20 descriptive.

Measurements of trash content in standards bales published in 1950.
23 Because of considerable criticism and misunderstanding at the 1946 conference regarding trash content levels in the cotton grade standards, measurements for Shirley Analyzer trash content, averages and standard deviations, as shown in the following table, were assembled and published for grade standards bales to provide a basis for better understanding of the extent to which the Department was adapting laboratory measurement methods to aid the classer in maintaining standards on a constant level.

---

* Amendment Sheet 2.

Table 2.--Percentage nonlint reported in 1950 for bales used in cotton grade standards

White grades No.	Shirley Analyzer percent nonlint				
	1936 standards bales		1946 standards bales		Smoothed curve
	Av.	S.D.	Av.	S.D.	
2			2.26	±0.26	2.0
3	2.94	±0.83	2.38	±0.29	2.4
4	3.63	±0.44	3.51	±0.67	2.9
5	3.83	±0.45	3.69	±0.15	3.7
6	5.35	±0.73	5.12	±1.32	5.1
7	8.08	±1.37	7.71	±1.74	7.6
8	11.03	±2.25	11.25	±1.44	11.0
9	18.64	±4.13	15.17	±4.20	17.0

1950 Universal Cotton Standards Conference. The ninth Universal Cotton
21 Standards Conference was convened in Washington May 1, 1950. A total
82 of 1,055 boxes was examined and approved as copies of the original 1946
Universal Standards.

At a second meeting the following three proposals from the European delegations were considered:

(1) That Middling Fair be eliminated and Strict Good Middling be retained as a physical standard.

(2) That physical standards be prepared for Spotted and and Gray cotton.

(3) That separate standards be provided for irrigated cotton.

No action was taken on the first proposal, and it was agreed that the second proposal would be considered in preparing for the next conference. The third proposal led to considerable discussion. The decision was that it should be considered in the revision of the standards.

In preparing for consideration of a change in standards, the United States Department of Agriculture indicated that a careful survey of current crops would be made before the next conference to determine how well present standards fit these crops, and that the results would be displayed to interested persons before the next conference.

This was a most harmonious conference. Representatives of all participating groups expressed pleasure and satisfaction with the Department and its staff in the successful matching of grade boxes against the 1946 standards. It was the first conference in which methods of technical measurements used in preparation of the standards were presented in any detail to a standards conference (by large charts, and a report[21] available for distribution to conferees), and this work was received most cordially. The electronic cotton colorimeter on display, was new in 1950, and this development compared to the visual methods of

colorimetry used in previous years, was of much interest to conference delegates, as was the fact that for the first time every sample used in preparing the 1950 boxes had been measured for color before being used.

American Egyptian Grade Standards Meeting, 1951. A meeting was held
83 June 25, 1951, to consider revision of grade standards for American Egyptian cotton. Results of recent crop surveys showed that the color of American Egyptian cotton was considerably whiter than the standards revised in 1940. This probably was caused by the fact that the variety represented in Pima standards was no longer grown, and that the SxP variety in the 1940 standards revision was rapidly being replaced by Pima 32 and Amsak varieties. These varieties are so nearly alike that it would be impractical to distinguish between them for the purpose of standardization.

Prior to the conference, a set of proposed new grade standards had been shown (by Hughes Butterworth) to various members of the cotton industry and trade for suggestions. The principal change proposed was in color.

Following a request for additional comparison of leaf for Grade 2, which was found to be satisfactory, the chairman (Rodney Whitaker) indicated that in the future it was the intention that leaf would be measured by the Shirley Analyzer for cottons used in the revised boxes. Mr. Slade commented on the "unusually sharp light" that made the boxes look unusually white, but after viewing the boxes and being shown diagrams of supporting color measurements, the new boxes were accepted by the group in a unanimous vote of approval.

Two other matters—use of the colorimeter in the future for control of color, and renumbering of the grades—were discussed.

A brief history of standards for American Egyptian cottons from 1913 to 1950, together with pertinent correspondence and a copy of the order establishing the new grades are included in the published proceedings of the 1951 meeting.

Revision of grade standards for American upland cotton, 1951-52. Fol-
24 lowing the 1950 conference, a careful survey was made of the color and
84 grade of the 1950 crop of American upland cotton. It was found that
85 compared to previous crops this one was no different in general color
103 than others of recent years. It was found that cottons from all areas were either on the white side of the standards, or were whiter (grayer in the low grades) than the cottons in the standards as they were passed at the 1950 conference. Practically all higher grades were white enough to be called Extra White on standards passed at the 1946 or 1950 conferences. The survey provided unmistakable information that there was a need for change in the color of the standards. Survey samples, received from all cotton growing areas of the United States, provided the representative samples that were needed to make up a preliminary new set.

It was determined both by classification and laboratory determinations that the most important necessary change was one of color, one that would shift the standards to whiter cottons (less yellow) so that the standards would represent cottons of current crops. It was not found necessary to change the general level of the grade standards. One other

major change was proposed, one already requested by many industry representatives. This was for a natural instead of an artificial standard, one in which samples are used as taken from the bale instead of artificial combing and smoothing of cottons, and artificial placement of leaf particles. A set of boxes based on these requirements was made up for White and Tinged grades for examination by American representatives and conference delegates. These were made in both 6- and 12-sample size boxes, the smaller box being recommended by the Department in replacement of the 12-sample size.

Representative American cotton associations were advised that the Department had made the promised survey of the 1950 crop, and were invited to send a small group of their experts to a meeting in Washington on August 7, 1951, to hear a presentation of the classification and laboratory results, to examine the resulting boxes, and to give their opinions regarding the suitability of these boxes as proposed new standards.

The shippers were in quite general agreement that these boxes were in the right direction. They thought the White grades a little better than the old standards, particularly in leaf; they strongly recommended physical standards for Spotted cottons, and requested a standard for Ordinary cotton. They expressed appreciation for the opportunity to review the proposed standards and felt that when their suggestions were incorporated into them, they would prove beneficial to all concerned.

The spinners found the White standards generally lower and duller than the old standards, and more rough in preparation but if they were to be accepted or rejected on a general basis they were willing to accept them. If changes were to be made in individual boxes to meet the shippers' recommendations, then they also had specific individual recommendations for several of the grades. They were quite willing to accept the 6-sample box. They would accept the standards prepared for consideration, but if any changes were made they would like to see the boxes again before approval.

Following this meeting of a small group of experts, a series of local meetings was held where all who were interested might hear a presentation of the classification and laboratory results of the survey, and review the proposed boxes. These meetings, all well attended, were held on August 22-24 at Charlotte, Atlanta, and Memphis; on September 5-7 at Dallas, Bakersfield, and New Orleans; on September 12 at Boston, and on September 18 at Houston.

For the most part, the boxes were well received, with general comments about as in Washington. The most critical comments indicated the color as generally too good in the White grades, with too little leaf. On the other hand, there were others that thought the proposed standards were too low.

On November 6-7, 1951, the proposed standards boxes were shown by Department representatives (R. Whitaker, H. C. Slade, D. Nickerson) at Le Havre, where the European committee of the Universal Cotton Standards Agreement met to hear the story and examine the boxes. The proposed standards were well received. They were accepted in principle, including new Spotted boxes. Opinion concerning box size was divided.

In the months that followed, bales were assembled and carefully tested for use in making up sets of boxes based on those shown at the 1951 meetings. The cotton used for the proposed White grade boxes was selected to represent each of four major producing areas, including irrigated cottons. All bales used were required to meet both classification and laboratory specifications; each was carefully screened on the Shirley Analyzer to accord with trash levels reported in 1950 for the standards, and every sample used was measured on the cotton colorimeter to conform with a color diagram based on the boxes shown at the 1951 meetings.

On June 7, 1952, after the boxes were ready, notice was given in the Federal Register[84] regarding the proposed revision, and a public meeting was called in Washington, June 19, 1952, to review the results and consider the proposed revised standards. The new boxes were presented in the 6-sample size only, since the weight of opinion at the various meetings, particularly when the "indifferent" and "for" votes were combined, seemed to favor it.

With suggestions for some modification the proposed standards were approved by virtually all of the producer, shipper, and merchant groups, as well as most cotton exchanges in this country; most urged that they be promulgated as 12-sample boxes. The most serious objection was that of domestic mill representatives who requested among other things that the color and preparation be raised. A change of this nature would have meant delay of another year, since it would mean searching for new bales, testing, and preparing them, and then calling a new meeting since it was agreed that no change would be made in the boxes without giving all interested groups an opportunity to help work out any compromise. It was announced by the Department that the views of the signatories to the Universal Standards Agreement would be obtained before a decision would be made whether to promulgate or attempt to work out a compromise.

A meeting of the signatories was held at Le Havre July 17-18, 1952, with Department representatives (R. Whitaker, H. C. Slade, D. Nickerson, H. Butterworth). Detailed laboratory test data on color and trash content of the crop surveys on which the suggested changes were based, and on bales bought to represent these changes in the proposed standards, were presented for consideration, along with classification data. After hearing the full story and seeing the results, the boxes were approved.

After giving due consideration to all relevant matters presented at the preliminary meetings, and in correspondence, new official cotton grade standards based on the proposed boxes were promulgated by notice of August 15, 1952 in the Federal Register,[85] to become effective August 15, 1953.

This revision of grade standards included the following changes:

(1) Elimination of Middling Fair and Strict Good Middling White and all grades of Extra White.

(2) Remaining standards changed to reflect color, leaf, and preparation characteristics of recent crops, and use of a "natural" standard.

(3) Numerical designations for grades were deleted.

(4) Good Middling and Good Middling Tinged were made descriptive.

(5) Retention of Spotted grades as descriptive standards.

(6) Retention of the 12-sample box to represent official standards in physical form, with 6-sample boxes added for distribution as practical guides.

In number the standards were reduced to the 10 physical grades and 14 descriptive grades listed in table 3.

Table 3.--Universal standards for grade of American upland cotton, 1953

Gray	White	Spotted	Tinged	Yellow Stained
*GM Gray	*Good Middling	*GM Spotted	*GM Tinged	*GM Yellow Stained
*SM Gray	Strict Middling	*SM Spotted	SM Tinged	*SM Yellow Stained
*M Gray	Middling	*M Spotted	M Tinged	*M Yellow Stained
*SLM Gray	Strict Low Middling	*SLM Spotted	SLM Tinged	
	Low Middling	*LM Spotted	LM Tinged	
	Strict Good Ordinary			
	Good Ordinary			

* Descriptive

The order establishing these standards included the averaging rule, and provided for use of the alternative title, "Universal Standards for American Cotton."

86 <u>1953 Universal Cotton Standards Conference</u>. The tenth Universal Cotton Standards Conference was held in Washington, D. C., May 1953. Sixty-five full sets plus several partial sets of copies of the revised standards for American upland cotton promulgated August 12, 1952, were examined and approved.

At a meeting held under the principal agreement, three topics were considered: 1, a physical standard for Good Middling; 2, physical standards for the principal grades of Spotted cottons; and 3, a revision of the Universal Cotton Standards Agreement.

While the Department did not consider either of the first two proposals desirable, nevertheless boxes had been prepared for inspection. Agreement was reached that Good Middling be made a physical standard, at least for leaf and preparation, even if color could not be found a full step above Strict Middling. A box representing this grade was approved, to become effective August 1954. After considerable discussion, it was agreed that physical standards for Spotted grades should not be adopted at this time, but that boxes should be prepared for field trial use during the next three years, to see whether they would deteriorate more rapidly than the White grades. This had been an earlier objection to their adoption as physical standards.

At this conference, spokesmen for American spinners, although they expressed approval of the work done in matching the boxes to the 1952 key sets, adhered to their opinion that the standard itself had been lowered in 1951, and did not therefore sign the usual certificate of acceptance. Representatives of all other American and signatory groups signed the certificate of approval of the new boxes.

<u>1954 Universal Cotton Standards Conference for Good Middling</u>. A special
87 conference was held June 7, 1954, at Washington, D. C., to inspect key sets to match the original Good Middling standard approved at the 1953 regular conference. There was, however, considerable discussion. The spinner group insisted that the standard was low. Shippers thought it was representative of the Good Middling cotton produced in the United States. The Department indicated it was the best cotton they could get, that it fully matched the leaf and preparation of the Good Middling standard adopted in 1953, and that measurements showed it was well up to or above the color of the box approved at the 1953 conference. The conference approved 299 boxes.

<u>Linters Conferences, 1954, 1955, 1956</u>. Up to 1955, linters standards
80 remained unchanged from the time they were first established in 1926.
97 The 1926 standards consisted of seven physical grades and one descrip-
107 tive grade for hull fiber. They were based on staple, character, color, and foreign matter and represented the Southeastern, South Central, and Southwestern qualities. These standards were based on condenser type linters.

As processing methods changed, and new uses were found for linters, cotton linters brokers, cottonseed crushers, and other representatives of the industry requested new standards.

Preliminary measurements made in 1951 on linters standards and on crop survey samples, made it clear that the color pattern of linters samples was closely connected with their grade pattern. In 1952 a survey of the industry was made. On the basis of this survey, and of methods developed for measuring quality factors, a conference was held on July 20, 1954, at which 50 condenser type standards were approved. General recommendations indicated, however, that standards should be based on flue, or beater type linters. Therefore, after numerous interviews with the people directly concerned with linters to get their opinion and advice, a linters conference was held in Washington, D. C., May 9, 1955.

At this conference, sets of condenser type standards were inspected and approved. Then new standards for beater type linters were proposed. Nine grades were presented to represent felting type linters, but the conference reduced these to seven that covered the old grades One Middle to Five Low. The old grades 6 and 7 were made descriptive, as "chemical" grades in the new standards. Thus the revised standards consisted of 7 physical grades, 1 through 7, and a descriptive grade for linters lower in grade, designated "chemical." It was agreed that these new standards would contain linters to represent the Western, South Central, Southwestern, and Southeastern Areas.

The proposed standards were adopted, and were promulgated to become effective July 1956. In the development of these standards, laboratory methods were extensively used. Grade includes color and trash. The color was established on the Nickerson-Hunter Cotton Colorimeter, and a grade diagram based on the new standards was adopted that has been in use since 1955.

In June 1956 a representative group from the linters industry met to examine and pass on copies of the grade standards approved in 1955, and to assist in selecting and approving types for staple standards.

Staple refers to length distribution of fibers in cotton linters, and this was measured by length arrays or Fibrograph measurements for fiber 1/4 inch and longer, and by a determination of weight loss from a Shirley Analyzer determination which correlates very well with the average fiber length of linters. Resistance or "drag" was also determined, and an evaluation of both the length distribution tests and separation resistance test was used to indicate staple value. In obtaining samples for use in standards, they were measured on the colorimeter for grade, and on the Fibrograph (for length index) and incline plane tests (for resistance to separation) for staple.

The group approved the staple types, and these were promulgated in 1956, to become effective June 1957. While preliminary measurements had been made on the types presented to the group, after the conference those selected for promulgation were analyzed and reported for length index, mean length, and resistance to separation.

Official standards established for fiber fineness and maturity, 1956.
97 Official cotton standards of the United States for fiber fineness and maturity were established effective January 15, 1956. These standards apply only for the purpose of making official determinations of fiber fineness and maturity by the Micronaire instrument on cotton delivered in settlement of futures contracts, but not for purposes of the United States Cotton Standards Act.

Revision of Universal Cotton Standards Agreement, 1956. In order to
90 combine the principal agreement and all supplemental agreements into one document and to incorporate certain administrative and procedural changes, a revision of the Universal Cotton Standards Agreement was consummated effective February 16, 1956. A copy of the revised agreement is included with the report of the 1956 Universal Cotton Standards Conference.

This Agreement was made between the United States Department of Agriculture and the following signatory associations:

Centro Algodonero Nacional, Barcelona, Spain
Bremer Baumwollbörse, Bremen, Germany
Marché de Coton de Gand, Ghent, Belgium
Association du Marché des Cotons au Havre, Le Havre, France
All Japan Cotton Spinners' Association, Osaka, Japan
Japan Cotton Traders' Association, Osaka, Japan
Osaka Sampin Exchange, Osaka, Japan
Liverpool Cotton Association, Ltd., Liverpool, England

Federation of Master Cotton Spinners' Associations, Ltd., Manchester, England
Manchester Cotton Association, Ltd., Manchester, England
Associazione Cotoniera Italiana, Milan, Italy
De Vereeniging voor den Katoenhandel, Rotterdam, The Netherlands
East India Cotton Association, Bombay, India

<u>1956 Universal Cotton Standards Conference</u>. The eleventh Universal
26 Cotton Standards Conference was held in Washington, D. C., May 21-23,
90 1956, for the purpose of examining and approving copies of the 1953
97 standards. As a result, 95 full sets, and an additional 605 boxes,
were approved.

By unanimous consent three topics were considered:

(1) A proposal to promulgate standards for Spotted cotton in physical form: After 3 years' field trial use of boxes for Spotted cottons, and a consideration of laboratory tests and comparison of storage results with those for White cottons, most opinions were that Spotted standards could be made that would be durable enough for practical use. However, both the spinner and producer groups were opposed, and the Department was unwilling therefore to vote for promulgation of Spotted standards in physical form. Field trial use of boxes for Spotted grades was continued for an additional 3 years.

(2) A proposal to establish a descriptive standard for Strict Good Middling: This proposal was approved, and a standard was promulgated July 1956, effective August 1, 1957.

(3) A proposal that the validity period of the grade standards be reduced from 18 to 12 months: Laboratory tests were discussed with the conferees regarding changes in standards returned after use. These showed that color deteriorates more rapidly in use than had been supposed. This lowering of color through use, plus the yellowing that occurs during usual conditions of storage, all pointed to the desirability of reducing the validity period of the grade boxes from 18 to 12 months. Since preliminary storage tests indicated that under a combination of low temperature and humidity the change in cotton color might be held to a minimum, the conference was informed that a basement vault had been air-conditioned, close to 45-48° F., and that sets passed at this conference would be placed in this vault immediately after the conference so that a fresh set of boxes could be sent to each signatory in 1957 and again in 1958. Meanwhile, during the next 3 years a controlled experiment would be made to discover the optimum conditions of temperature and humidity for the most practical storage of standards between conferences. No objection was raised to changing the validity period of grade standards to 12 months.

Announcement was made to the conference that before the next meeting, unless there was objection, the natural skylights in the classing room where the Universal Cotton Standards Conference was held, would be replaced with artificial lighting, since practically all cotton in the United States was now being classed under artificial lighting.[1]

American Egyptian Grade Standards Meeting, 1956. This meeting was held
91 on May 23, 1956 in Washington, immediately following the Universal Grade
92 Standards Conference. The last revision had been made in 1951. Observations of recent crops, particularly a survey of the 1955 crop, indicated that significant changes had taken place in the appearance of this cotton since 1951. There were changes in varieties produced, and changes in harvesting practices. The 1951 standards were prepared from Pima 32 and Amsak varieties, while by 1955, practically all cotton grown was Pima S-1. A set of boxes representing these changes had been prepared and shown to industry representatives in eight producing and selling areas, and the set proposed in Washington contained as nearly as possible all suggestions received. The Department, after taking under advisement the difference in opinion expressed at the meeting, recommended promulgation as official standards with only a few minor adjustments.

A later meeting was called on June 5 to consider slight changes that it was hoped could result in unanimous approval. After minor adjustments in grades 1-5, unanimous approval was reached for grades 1 to 9 in physical form, grade 10 descriptive. The standards were promulgated June 28, 1956, effective August 1, 1957.

94 Revised regulations were issued October 1956 for cotton classification under Cotton Futures legislation.

1959 Universal Cotton Standards Conference. The twelfth Universal Cotton
27 Standards Conference was held in Washington, D. C., May 1959. The Gdynia
28 Cotton Association of Gdynia, Poland, a member of the Agreement since
29 May 8, 1958, was welcomed as the newest signatory to the Universal Cotton
30 Standards Agreement. One hundred sixty-three full sets and 99 additional
35 boxes were examined and approved as copies of the 1953 standards.

98

99 Several matters were presented to the conference for consideration. In accord with an understanding at the 1956 conference, two sets of standards approved in 1956 were held under refrigeration for each signatory association, one forwarded in 1957, the other in 1958. It was announced that this procedure seems to have been useful, and would be continued. It was also announced that since the last conference a change had been made in the validity period for the grade standards by reducing it from 18 to 12 months.

Based on favorable results of continued field trial boxes of Spotted cottons, and on considerable support for the change, it was recommended that physical standards for Spotted grades be promulgated without further delay. Because separate price support rates for split grades were now in effect, it was urgent that official descriptive standards be promulgated for them. This includes descriptive standards for the long recognized descriptions of Light Spotted cotton, for Light Gray, and for Plus cottons (Middling Plus to Good Ordinary Plus, in which the color is better than the leaf of the named grade, e.g., Middling Plus is cotton which is Middling in leaf and preparation with Strict Middling color). An official definition was requested for Below Grade cotton.

The need for a physical standard for Strict Good Ordinary Spotted cotton had been suggested, and boxes were available representing this grade.

Application and interpretation of the averaging rule, which had been a part of the standards since their promulgation in 1922, had been under considerable criticism, and the Department indicated that it would welcome having the conference discuss the pros and cons of the present wording. Some groups even wished to change it so that the grade would be assigned on the lowest factor, without consideration of other factors. The Department proposed a method for specifying grade factors separately in order to provide a more complete description of cotton quality when the factors do not match a single standard. A code method of recording such descriptions (e.g., "Middling color, Good Middling leaf" would be coded as M^{+2}; "Middling color, Strict Low Middling leaf" would be coded as M^{-1}) was presented. The code came in for much criticism, even though many expressed agreement with the principle of describing a sample in terms of its separate factors.

Results of surveys of the 1957 and 1958 crops were presented to the conference. These showed a significant reduction in leaf in the various grades, undoubtedly one of the causes being an increase in the use of cleaning and drying equipment at the gin. To provide standards to take care of such changes either a change should be made in the designation for grade to terms descriptive of separate grade factors, or the standards should be revised so that the combination of factors represented in each grade standard would represent the combination that occurs most frequently in that grade. A set of boxes reflecting the reduced trash content shown in surveys of recent crops was displayed to the conference.

Results of studies concerned with laboratory measurements of standards, surveys, trash and color content of grades, and of color change in storage, were distributed to conferees. Charts included in these studies were discussed with them as background information concerning the need for the change proposed in the standards. It was pointed out that cottons in current crops were averaging at least one grade less in trash content than is required for use in the standards. This meant that the principle of using a natural standard had been abandoned, for to make up standards to match those adopted in 1953 it had become necessary to add trash to the surface in order that the biscuits in each grade box match those in the standards. It was pointed out that from a classification, as well as a laboratory point of view, the leaf in the proposed revision set was a full grade less than in the standards. The proposed set was made from survey samples, with a minimum of leaf adjustment, while to prepare the standards boxes passed at this conference, it had been necessary to add leaf in order to obtain a match to the 1953 standards.

Also displayed at this conference were boxes containing 1956 sets of standards samples that had been stored since 1956 under various controlled conditions of temperature and humidity. After 3 years' storage there was a color change for all conditions. Cotton held at 50° F., 50% R.H. showed erratic, but very small changes; at 100° F., 50% R.H. there were large changes; at 100° F., 90% R.H., the changes were very large. Boxes were displayed with three rows of cottons originally the same, but each row taken from cotton stored for 3 years under one of the above three conditions. The results, compared in this manner, showed startling differences. For the first time many of those attending the conference had firsthand evidence of the very considerable amount of color change that can take place in cottons, particularly in the high grades, when they are stored

under conditions of temperature and humidity that are not at all unusual in many cotton warehouses. While cottons stored at 50° F., 50% R.H. did not change in grade in 3 years, the same cottons when stored under other conditions, changed as much as from White to Tinged grades.

It was announced that while it is still the intention to prepare boxes that will represent the four areas of production, in a few boxes it had been found necessary to deviate from this rule. Such deviations would be held to a minimum.

Another change, to begin the following season, specified that all boxes sold during the season be dated July 1, and thus expire on June 30 of the following year, regardless of the date of purchase. Usually enough grade boxes are prepared at the beginning of the season to last throughout the season.

After considerable discussion of the pros and cons of these many questions, the conference, in addition to approving boxes for the physical standards of White and Tinged cotton, decided not to accept the code method proposed for designating grade in terms of separate factors, nor to make the general revision proposed to take care of the change in leaf. It was agreed that the following standards should be promulgated; and this was done on June 22, 1959, effective August 1, 1960:

(1) Official physical standards for Strict Middling Spotted through Low Middling Spotted, Good Middling Spotted to remain descriptive.

(2) Official descriptive standards for Good Middling Light Spotted through Low Middling Light Spotted.

(3) Official descriptive standards for Middling Plus through Good Ordinary Plus.

(4) Official descriptive standards for Good Middling Light Gray through Strict Low Middling Light Gray.

(5) An official definition for Below Grade cotton.

It was agreed that the wording of the official descriptive standards for Gray cotton be revised slightly.

Effective August 1, 1960, this made a total of 39 standard grades for American upland cotton, 15 in physical form, 24 descriptive, as shown in table 4.

<u>Staple standards amended, 1960</u>. An amendment to the Official Cotton Stand-
100 ards of the United States for Length of Staple, issued August 1, 1960,
effective August 1, 1961, listed the following lengths represented by
cotton in the custody of the U. S. Department of Agriculture in containers
suitably marked with the name of growth, appropriate designation of staple
length, and the effective date:

American upland		American Egyptian		Sea Island	
Aug. 1, 1929	7/8	Aug. 1, 1929	1-1/2	Aug. 10, 1939	1-1/2
	15/16	Aug. 10, 1943	1-3/8		1-9/16
	1		1-7/16		1-5/8
	1-1/32	Aug. 1, 1961	1-5/16		1-3/4
	1-1/16				
	1-3/32				
	1-1/8				
	1-5/32				
	1-3/16				
	1-7/32				
	1-1/4				
Aug. 1, 1933	13/16				
	29/32				
	31/32				

Other standards remain descriptive. An historical summary of staple standards, in orders promulgated 1918 to 1960, is given in table 5.

Table 4.--Universal Standards for grade of American upland cotton, 1960

Gray	Light Gray	White		Light Spotted	Spotted	Tinged	Yellow Stained
		*Strict Good Middling	SGM				
*GM G	*GM Lt G	Good Middling	GM	*GM Lt Sp	*GM Sp	*GM Tg	*GM YS
*SM G	*SM Lt G	Strict Middling	SM	*SM Lt Sp	SM Sp	SM Tg	*SM YS
		*Middling Plus	M +				
*M G	*M Lt G	Middling	M	*M Lt Sp	M Sp	M Tg	*M YS
		*Strict Low Middling Plus	SLM +				
*SLM G	*SLM Lt G	Strict Low Middling	SLM	*SLM Lt Sp	SLM Sp	SLM Tg	
		*Low Middling Plus	LM +				
		Low Middling	LM	*LM Lt Sp	LM Sp	LM Tg	
		*Strict Good Ordinary Plus	SGO +				
		Strict Good Ordinary	SGO				
		*Good Ordinary Plus	GO +				
		Good Ordinary	GO				
.... Below Grade							

* Descriptive

Table 5.--Summary of Official Cotton Standards of the United States for length of staple, 1918 to 1961. Checks indicate physical types, stars represent descriptive standards

Lengths (inches)	Effective dates										Physical standards Aug. 1, 1961#		
	1918	1921	1924	1926 AU	1926 AE	1929 AU	1929 AE	1933 AU	1939 SI	1943 AE	AU	AE	SI
Below 3/4	*												
3/4	√			√		√							
13/16	*							√			√		
7/8	√			√		√					√		
29/32								√			√		
15/16	*		√	√		√					√		
31/32								√			√		
1	√			√		√					√		
1-1/32	*			√		√					√		
1-1/16	*	√		√		√					√		
1-3/32	*			√		√					√		
1-1/8	√			√		√					√		
1-5/32	*			√		√					√		
1-3/16	*	√		√		√					√		
1-7/32	*			√		√					√		
1-1/4	√			√		√					√		
1-9/32	*			√		√							
1-5/16	*	√		√		√						√	
1-11/32	*			√		√							
1-3/8	√			√		√				√		√	
1-13/32	*												
1-7/16	*									√		√	
1-15/32	*												
1-1/2	√			√	√	√	√		√			√	√
1-17/32	*												
1-9/16	*				√		√		√				√
1-19/32	*												
1-5/8	√				√		√		√				√
1-21/32	*												
1-11/16	*												
1-23/32	*												
1-3/4	√				√		√		√				√
and upwards in 32nds	*												

Effective date.

1962 Universal Cotton Standards Conference. The thirteenth Universal
32 Cotton Standards Conference was held in Washington, D. C., May 24-25,
102 1962, to approve key sets of copies of the 1953 standards and to con-
sider a proposed revision of the 1953 standards.

Delegates represented 14 cotton associations in Belgium, England, France, Germany, India, Italy, Japan, Poland, Spain, and the Netherlands and 42 industry groups in the United States.

At the 1959 conference, delegates had opposed the change in standards requested by the Department to reflect the decrease in trash content found in recent crops. Following the 1959 meeting annual crop surveys were continued. The data were compiled in a report that discussed how these trends in trash content of raw cotton had created a problem in grade standards because of the change in relation of the color, leaf, and preparation factors that combine to make grade. The data indicated conclusively that in current crops the grades not only contained far less trash than the 1953 standards, but the size of the trash had changed, and the color was more diffused throughout a sample than formerly, so that there were fewer identifiable spots. It was pointed out that harvesting and ginning methods had changed drastically in recent years—for one example, in 1948 only 28 gins had lint cleaners, but by 1961 90 percent of the 5,619 gins in the United States had lint cleaners.

In preparation for the May conference a small working group representing the United States cotton industry met in early March with Cotton Division staff members to go over the information and samples that had been assembled, and to develop a proposed revised set of standards for White, Spotted, and Tinged cotton. The group included representatives of producers, ginners, shippers, and manufacturers organizations. Working with Cotton Division experts, a proposed revised set was developed and approved.

This set of boxes was displayed at meetings held in March and April at eight central locations in the United States. In April and early May representatives of the Department (A. C. Robison and J. H. Melancon) met with overseas signatories of the Universal Cotton Standards Agreement at several locations in Europe and Asia. Thus, by the time of the conference, a majority of delegates already had seen the proposed set and were acquainted with the reasons that made a revision necessary.

During the May conference delegates examined and approved 1,280 boxes against current standards for use during the coming year. They also reviewed the proposed revised standards, and with a few minor changes, approved them unanimously for White, Spotted, and Tinged grades. These were promulgated on June 7, 1962, to become effective June 15, 1963. The amended standards, with revisions noted in the physical standards, remain as listed in table 4.

Related Subjects

Grade and Staple Statistics Act, 1927. Legislation passed in 1927
44 directed the Secretary of Agriculture to collect and publish sta-
101 tistics on estimates concerning the grade and staple length of
cottons in the carry-over, and of current crops. (Public Law 740,
69th Congress, approved March 3, 1927, 44 Stat. 1372; 7 U.S.C.,
471-476.)

Standards for grades of cottonseed, 1932-1946. Official standards
16 of the United States for the grading and analysis of cottonseed for
95 crushing purposes were first established on May 23, 1932 under au-
96 thority of the 1932 Appropriation Act for the Department of Agri-
culture. They were, and still are, permissive standards. Since
1946 they have been authorized under the Agricultural Marketing Act
of 1946.

Classing and Market News Services established, 1937. Legislation
79 providing for free cotton classing and market news services for
89 producer cotton improvement groups was passed on April 13, 1937.
This was accomplished by the Smith-Doxey amendment to the Grade and
Staple Statistics Act of 1927. (Public Law No. 28, 75th Congress,
50 Stat. 62; 7 U.S.C., Sec. 473 a, b, and c.) The 1960 amendments
provide penalty provisions for offenses related to sampling for
classification. (Public Law 86-588, approved July 5, 1960, 74 Stat.
328-329.)

Cotton-Fiber Testing Service authorized, 1941. In consequence of
79 requests from cotton breeders, legislation was approved April 7,
1941, authorizing the government to make fiber and spinning tests
for breeders and others, on a fee basis. This was by amendment to
the 1927 Grade and Staple Statistics Act. (ch. 42, 55 Stat. 131.)

International Cotton Calibration Standards Program. In 1956, an
104 International Cotton Calibration Standards Program was initiated
to provide standard cottons by which cotton fiber testing labora-
tories might calibrate their instruments and maintain a uniform
level of test results. The program is sponsored by the American
Cotton Manufacturers Institute, American Cotton Shippers Associa-
tion, International Federation of Cotton and Allied Textile
Industries, the National Cotton Council of America, and the United
States Department of Agriculture. The program is operated by the
Cotton Division, Agricultural Marketing Service, U. S. Department
of Agriculture, in behalf of a committee representing the sponsor-
ing organizations. Calibration cottons are prepared and distributed
to member laboratories, and semi-annual check tests are conducted.
Calibration cottons were first established for micronaire fineness
and Pressley fiber strength tests.

Cotton standards throughout the World. In 1962 the International
10 Advisory Committee reported on a survey it had made of cotton
standards used by its member countries. Results indicated that
while some countries have standards, the most widely used by many
countries producing upland cottons are the Universal Standards for
American cotton.

Laboratory Methods Related to Standards Work

1 Manufacturing tests. As far back as 1914, manufacturing tests have been
5 made on cottons representing standards. Manufacturing tests on standards
7 13 bales are still being made today. Meanwhile, new methods of testing have
14 been developed, or old ones improved, so that it is now possible to make
33 more precise and detailed studies of relationships between fiber proper-
37 ties of cottons and their processing potential or resulting yarn proper-
88 108 ties.

Early test methods. A few of the test methods have been more particu-
3 larly related to standards work than others. In 1927, to provide quality
4 maintenance of cotton standards, a laboratory program was established in
18 the Cotton Division of the Bureau of Agricultural Economics. Work had
93 been published by the U. S. Department of Agriculture as far back as 1912
105 on staple, and in 1924 on a method for measuring fiber strength, but the
earliest studies designed directly toward maintaining staple standards
began in 1927 and were concerned with the measurement of length. In the
same year, studies began on the measurement of color in connection with
maintenance of grade standards.

Tests related to staple. Today, classing and laboratory tests must
12 agree within close length tolerances on any bale purchased for staple
106 standards. Both the Suter-Webb sorter and the Fibrograph are used, the
Fibrograph particularly for making preliminary checks on bales sub-
mitted by the classer. While much work is done by the laboratory in
connection with maintenance of the staple standards and methods of
quality control, very little has been published. The exceptions are a
brief paper by Whitaker in 1958, and one by Lord of the Shirley Insti-
tute in 1960, in which he reported on the consistency of staple length
classification represented by standards which he had obtained and tested
between 1935 and 1958.

The methods of test used in the staple standards work have been stand-
1 ardized and published, the array method as ASTM D1440-55, the Fibro-
graph method as D1447-54T. (A recent model Digital Fibrograph automat-
ically indicates length, thus eliminating the uncertainty involved in
drawing a tangent to a curve as required in earlier models.)

Tests related to color factor of grade. Early work on the grade stand-
18 ards, by a visual cotton colorimeter, developed about 1927-29, made it
20 possible to study the relation of the grades to each other in color; to
make measurements of standards when originally prepared, and again after
a period of years to discover the change during storage; to check the
color of bales purchased for standards; and study results of crop sur-
19 veys to learn how well standards continue to fit current crops. In 1950
21 an electronic colorimeter especially developed for use with cotton was
22 used for the first time in preparing for a grade standards conference.
Because of the speed and precision of this instrument, it became possi-
ble to measure each biscuit, as well as each bale, used in the standards.
A report prepared for the 1950 conference contained cotton grade-color
diagrams that showed in detail the relation between measurements made
by the old and new methods.

A second report on the application of the electronic colorimeter
24 was prepared for the 1953 grade standards conference; it discussed
factors considered in preparing standards, and described the devel-
opment of the 1952-53 standards in detail that is not available
elsewhere. In 1954, color measurements were reported for a group
25 of old and new standards that included some as far back as 1909, in-
cluding the early Liverpool standards; the cottons in these early
standards had changed with time, but nevertheless they provided
background information very useful in interpreting current standards.

At the 1956 grade standards conference a report was circulated that
1 contained diagrams and tables to illustrate the progress of labora-
26 tory work on 1950-1956 grade standards by color measurements and by
Shirley Analyzer tests for nonlint content. It contained details
for original standards and bales, for sets issued at and between con-
ferences, information on color change of standards after storage and
after use, and data for color and trash of American upland and
American Egyptian cottons, and for cotton linters of current crops.

For the 1959 conference, a series of four reports were compiled.
27 They cover measurements of grade standards, 1952-59; measurements of
28 crop surveys, 1951-58; measurements of trash and color of cleaned
29 lint; and a summary of color change of 1956 standards after one and
30 three years of storage under controlled conditions of temperature and
humidity. Samples of these stored cottons on display at the 1959
conference caused quite a stir, because many who saw them had never
before been able to visualize the extent of color change possible
under conditions of storage that are not at all unusual. Of the high
grade White cottons displayed, those held under storage conditions of
100° F., and 85-90% relative humidity had lost as much as 35% of their
value in 3 years by changing color from White to Tinged, while dupli-
cate samples from the same bales showed little—if any—change after
storage for 3 years at 50° F., 50% relative humidity.

For the 1962 conference, diagrams representing the color of the
102 standards were made available to the conferees, both for the sets to
be matched against the old standards, and for the set proposed for
revision.

31 The most recent general report on the cotton colorimeter and its use
is one prepared in 1960 for an ACMI Open House at Clemson, S. C.

Tests related to trash factor of grade. Regarding the trash factor
23 in the grade standards, measurements of Shirley Analyzer nonlint
24 content have been made from the time of the 1950 conference on all
38 bales used in the standards. Prior to 1950, these measurements were
made as a matter of record only, often after the bales were used;
during those years the visual judgment of the classer was the sole
method used to maintain a constant level of trash content. But in
preparing for the 1953 standards conference, although all bales were
selected first by classification, none was used unless it also met
specifications for Shirley Analyzer nonlint content and for color.
In putting up standards in 1952 and 1953, the trash level that had
been used in standards for many previous years was met without trouble.

26 By 1956 the trash content of current crops was already changing. In the tables and diagrams submitted to the 1956 conference it was reported that "compared to the average of past standards, bales for practically all 1956 grades are lighter in trash than intended when bales were purchased." Even in 1956 trash had to be added to some boxes, but it was reported that "this has been kept to a minimum in order to hold to the principle of a natural standard." More trash studies were promised for the three years intervening before the next conference, particularly with a new Cotton Trashmeter for which a contract had been let.

29 At the 1959 conference, one of four laboratory reports was concerned with trash content in standards bales and in grades of recent crops. It included a report on a demonstration set suggested as a basis for revision of the standards. The average color of this set was on the level of the 1953 standards, with leaf about as it occurred in the original bales. The Shirley Analyzer nonlint content of the bales from which these samples were taken averaged one grade better than was required in order to match the trash content of the standards. As a matter of fact, with few exceptions this set was made from bales used in the 1959 standards, but without adding the leaf that it was necessary to add in order that the 1959 standards match the original 1953 standards. This was explained to the conference; in fact, in the reports provided to conferees, color diagrams included the same bale numbers for many of the cottons used in the two sets. (See figure 7, Report No. 1,[27] and figure 15, Report No. 3.[29]) Trash data for grade standards bales as far back as 1936, for grades in special color-trash surveys for crops back to 1947, and for annual cotton quality surveys for 1946 to 1958 are contained in tables 1 to 4 of Report No. 3.[29]

40 At the 1959 grade standards conference an experimental model of a new
41 Cotton Trashmeter, developed for the Standards work by the Outlook Engineering Corporation, was exhibited in the laboratory. Designed to scan the surface of a cotton sample rapidly, it measures trash on two scales, "Relative Area" and "Relative Count." This instrument, described in 1960, uses an optical-mechanical scanner. It measures particles as small as 0.01 inch, and requires no more than three seconds to scan a 4"x4" sample of cotton. Preliminary measurements made on this instrument for standards and crop bales in 1959 and 1960 were studied in relation to Shirley Analyzer and manufacturing waste data for the same bales, and similar studies will be continued until suitably calibrated scales can be adopted.

At the 1962 grade standards conference a new model Cotton Trashmeter was available with improved precision, and preliminary measurements made on it were included in laboratory reports made to the conference. Since then, the precision has been further increased, so that it should not be long before the Cotton Trashmeter can be well enough standardized and calibrated to schedule regular measurements on each biscuit put up for the grade standards, as already is customary for color measurements.

32 In preparation for the 1962 conference, trash and color surveys were
102 continued, and a report made of the results. This included a discussion of the problem created in grade standards work by the trend toward decreased trash content in cottons of current crops. The change in relationship of color, trash, and preparation in grades of recent crops

was pointed out, as was the increasing need either to class on separate factors, or to adjust standards to fit the changed combination of factors in current crops. The report made it increasingly clear how necessary it was that something be done to correct this situation. Standards committees of various trade groups made considerable use of this report in studying recommendations for a change in standards, and at the conference it was circulated to members. Discussion at the conference not only concerned the need for a change in amount of trash, but also in the size of leaf particles, and in the color of Spotted cottons. The change in spotted color is to account for color that today is more and more often blended throughout the sample instead of being evident as distinct spots.

Tests related to the preparation factor of grade. In regard to the
17 factor of preparation, very little laboratory work has been done. This is because spinning test results do not support the belief that differences in roughness or smoothness of preparation—even when very apparent to the eye—will be followed by equally apparent differences in spinning results. As a general rule, smoothly ginned cotton results in less waste, and produces a slightly smoother and more uniform yarn than roughly ginned cotton, but except for cases in which roughness is excessive enough to cause the cotton to be reduced materially in grade, laboratory experience does not show significantly lower results for yarn tests. Because of this, and because excess roughness can be detected by color measurements (by a reduction in reflectance, due to excess shadows) no special tests, beyond a visual examination by the classer, are under development by the laboratory for roughness as a factor of preparation. However, the definition of preparation includes "neppiness." While the laboratory has no easily applied method for establishing guides that can be used as a scale for specifying different degrees of this condition, it is hoped that one day a suitable method can be developed that will help the classer to detect and specify this factor in a practical way.

Use of Micronaire. Uses that are being made of the micronaire reading
43 in connection with standards work should be mentioned. It is used to
97 exclude bales with extreme micronaire readings from selection as standards bales, a practice that is followed for other measures also, in order to exclude use of extremes for any fiber factors other than grade or staple in the standards bales. A more direct use in standards is required for micronaire reading by its specification in the Internal Revenue Code of 1954 where, for purposes of Cotton Futures legislation but not for purposes of the Cotton Standards Act, Official Cotton Standards of the United States are provided for fiber fineness and maturity. The terms of designation, and the procedure are included as a part of the standard (Sec. 27.210-213[99]).

Potential use of instruments in specifying character factors of cotton.
33 In a less direct manner, use of instrument specifications is being applied in connection with standards by application to classing of irregular or special condition cottons, or cottons of varying quality elements for which standards are not yet specified. To provide aids for specifying such cottons, laboratory data are constantly under study to discover the significance of the relation of processed results to test measures that can be applied to the original raw cotton.

Many quality elements, usually grouped under the general term "char-
2 acter," are susceptible to such studies. Little by little, progress is
8 being made in linking the results of such work with direct or indirect
39 applications to standards. As an example, recent spinning test results
42 on a group of "unusual character" cottons showed a significant relationship between micronaire readings and cottons described by classers as "soft," "irregular," "weak," and "wasty." Results also showed a significant relationship with the waste content and neppiness of the raw cottons, and with the quality of yarn made from them. As a result of these and other studies, a micronaire reading of 2.6 was found to be the borderline beyond which all cottons studied were called "wasty" by classification. Spinning tests invariably showed that cottons with a micronaire reading of 2.6 or lower were immature, neppy, with waste content above average for their grades, and that they produced yarn of poor appearance grades. There were no exceptions. On the basis of these studies, a 2.6 micronaire reading was set tentatively as the borderline below which cotton must always be designated "wasty." Cottons above 2.6 may also be called "wasty" by the classer, but all cottons below it must be called "wasty." However, since there is no one point on the micronaire scale where cotton suddenly becomes inferior, studies of this relationship are being continued, with the goal of developing a scale which will make it possible to specify different degrees of deterioration from borderline to normal cottons.

At present, the 2.6 micronaire limit is the only instrument specification included in instructions to classers that must be applied in arriving at his classification. Other instruments—the Suter-Webb sorter, the Fibrograph, the Cotton Colorimeter, the Shirley Analyzer, and the Cotton Trashmeter—are used as aids in preparing standards. But as an aid to the classer the use of any of these instruments is permissive rather than mandatory.

Similar studies of special condition cottons, that is, cottons with grass, bark, spindle twist, or that contain excessive amounts of fluorescent spot, are also under study. When tests are found that show sufficient relationship between varying degrees of the particular condition noted and the degree of deterioration in the resulting product quality, then it will be possible to provide specifications for these conditions that can be used either to improve present standards, or to increase the uniformity of classing against the standards.

Summary statement. From these foregoing discussions it should be evident that laboratory methods, as rapidly as they can be made sufficiently practical, are being developed and applied to standards work.

Bibliography

(1) American Society for Testing and Materials
ASTM Committee D-13 on Textile Materials, ASTM Standards on Testile Materials. 32nd edition, Oct. 1961. 993 pp. Published annually by Am. Soc. for Testing and Materials, 1916 Race St., Phila. 3, Pa.

Contains specifications, tolerances, methods of testing, definitions and terms standardized by Committee D-13 (Textiles). Included are the following:

D1440-55 Length Array
D1441-54 Sampling Cotton Fibers for Testing
D1447-54T Length of Cotton by Fibrograph
D1448-59 Micronaire Reading of Cotton Fibers
D1451-59 Nonlint Content of Cotton, Shirley Analyzer Method
D1684-61 Lighting Cotton Classing Rooms for Color Grading

(2) Campbell, M. E.
The Possibilities and Limitations of the Spinning Test as a Means of Determining Cotton Quality. Text. Res. VIII, 263-269, June 1938.

A discussion of the subject as useful today as when originally published.

(3) Chandler, E. E.
A New Method for Determining the Strength of Cotton. U. S. Dept. Agr., BAE,[1] 1926. 16 pp.

A description of "Chandler bundle-method" for determining fiber strength.

(4) Cobb, N. A.
An Accurate Method of Measuring Cotton Staple. Natl. Assn. Cotton Manufs. Bull., 1912. 26 pp., illus.

Cotton fiber length and length distribution by projection-map-tracer method; of historic interest, representing early thinking on testing methods.

(5) Cobb, N. A.
Tests of the Waste, Tensile Strength, and Bleaching Qualities of the Different Grades of Cotton as Standardized by the United States Government. Bull. U. S. Dept. Agr. No. 62, Jan. 14, 1914. 8 pp.

Experiments described to ascertain facts regarding fiber, yarn and processing of cotton "that will assist in making the official cotton grades more useful and reliable." Preliminary results are reported for tests at Riverside and Dan River Mills of 10-12 bales each of five grades of 1-inch Atlanta and upland cottons, from 1912 or earlier crops, these

---

1 Bureau of Agricultural Economics.

tests to be supplemented by tests at Clemson Agricultural College and North Carolina Agricultural and Mechanical Textile School. Significant results reported for mill waste only, from about 4 percent in Middling Fair to 11 percent in Good Ordinary.

(6) Conrad, Carl M., and Webb, R. W.
The Problem of Character Standardization in American Raw Cotton. A preliminary report, U. S. Dept. Agr., BAE, July 1935. 19 pp.

(7) Dean, Wm. S., and Taylor, Fred
Manufacturing Tests of the Official Cotton Standards for Grade. U. S. Dept. Agr., Bull. No. 591, Dec. 26, 1917. 27 pp.

Spinning tests on eastern and western cottons from 1914 crop, five grades (MF, GM, M, LM, GO) to determine relative values. Spinning and weaving tests made in Fall River, Mass. and the textile department of the North Carolina State College of Agriculture and Engineering. Bleaching tests were made at bleacheries in Fall River and at the New Bedford Textile School. Waste percentages, yarn strength tests, and bleaching tests all showed a high relationship with grade.

(8) De Loach, R. J. H.
History of Cotton Classification. Trans. Natl. Assn. Cotton Manufs. Annual Meeting, April 24-25, 1912. No. 92, p. 316.

(9) Earle, D. E.
The Classification and Grading of Cotton. U. S. Dept. Agr. Farmers' Bull. 591, July 10, 1914. 23 pp.

Discusses history and purpose of cotton grading, factors that affect grading, foreign matter and color, establishment of standards for nine official grades, their care and use, relative commercial differences for staple and grade.

(10) International Cotton Advisory Committee
Survey of Standards Used for Classing Cotton. Published by Secretariat of International Cotton Advisory Committee, South Agriculture Bldg., Washington 25, D. C., May 1962. 44 pp.

Reports results of a survey of cotton standards used by member countries of the International Cotton Advisory Committee.

(11) Lane, Rachel P., and Day, Emily L.
Cotton and Cottonseed. U. S. Dept. Agr. Misc. Publ. 203, 1934. 149 pp.

A list of U. S. Department of Agriculture publications on these subjects, including early reports of the U. S. Patent Office.

(12) Lord, E.
II—Maintenance of Staple Length Standards in the U.S.A. Reprint from Vol. XXXIII, Shirley Institute Memoirs, May 1960. 14 pp.

An article on the maintenance and preparation of U. S. Official Staple Standards, reporting on consistency of staple length represented by standards obtained and tested 1935 to 1958.

(13) Lord, E.
Manual of Cotton Spinning. Vol. II, Part I, 333 pp., Textile Book Publishers, Inc., 1961, N.Y. (The Textile Institute, Manchester, England.)

Chapters 2 and 10 concern classification by staple and grade, and include general discussions of U.S. and other standards, particularly for grade. Other chapters describe laboratory methods for measuring fiber length, maturity, fineness, trash, etc.

(14) Meadows, W. R., and Blair, W. G.
Preliminary Manufacturing Tests of the Official Standards of the United States for Color for Upland Tinged and Stained Cotton. U. S. Dept. Agr. Bull. 990, Oct. 20, 1921. 12 pp.

GM, M grades of Tinged, Yellow Stained, and Blue Stained, and LM Yellow Tinged cottons, with LM White as a control, were tested under conditions used earlier on White grades.

(15) Meloy, G. S.
The Establishment of Standard Grades for American Cotton Linters. U. S. Dept. Agr. Misc. Publ. No. 10, Nov. 1927. 8 pp.

Review of movement leading to the establishment of standard grades for American cotton linters under authority of the Cotton Standards Act.

(16) Meloy, G. S.
Development of Standards for Grades of Cottonseed. U. S. Dept. Agr., BAE, June 1935. 31 pp.

Describes various aspects of cottonseed quality work, and the history of the movement to secure cottonseed standards.

(17) Newton, Franklin E.
Roughness as a Factor of Cotton Grade Measured by Spinning Tests. U. S. Dept. Agr., AMS,[2] Sept. 1959. 6 pp.

Report on the effects of rough preparation on the end results of cotton processing.

[2] Agricultural Marketing Service.

(18) Nickerson, Dorothy
A Method for Determining the Color of Agricultural Products. U. S. Dept. Agr. Tech. Bull. No. 154, Dec. 1929. 32 pp.

Describes earliest work in color measurements applied to cotton standards work. Includes discussion of disk colorimetry and of general principles involved in color work with other agricultural products.

(19) Nickerson, Dorothy
Cotton Standards in Vacuum and Non-vacuum, Compared to Set 707, 1929. Cotton Div. Office Report, Sept. 15, 1931. Available in files.

Includes report of colorimetric and classers' comparisons of several test sets of cottons.

(20) Nickerson, Dorothy
Color Measurements of Standards for Grades of Cotton. Text. Res. Jour., 16, 441-449, illus. 1946.

Color measurements of cotton standards shown in a series of diagrams, illustrating relation of grade to each other in color, and how the color may change over a period of years. The 1923 original standards, copies made in 1929, '31, '33, the 1935 originals, and copies made in '36, '39, and '44, and standards adopted in 1946, are shown, with remeasurements that show storage effects.

(21) Nickerson, Dorothy
Color Measurements of Cotton—Preliminary Report on Application of New Automatic Cotton Colorimeter. U. S. Dept. Agr., PMA,[3] Apr. 1950. 18 pp.

Report prepared for use at 1950 grade standards conference. Contains a brief background of cotton color measurement work and a description of the new automatic cotton colorimeter and its use in the preparation of cotton standards.

(22) Nickerson, Dorothy, Hunter, R. S., and Powell, W. G.
New Automatic Colorimeter for Cotton. Jour. Opt. Soc. Amer., 40, 446-449. 1950.

A description of the new and rapid electronic colorimeter that directly indicates the color of cotton grades. This instrument replaces the visual disk colorimeter previously used for measuring cotton color.

---

[3] Production and Marketing Administration.

(23) Nickerson, Dorothy
Foreign-Matter Content in Bales of Cotton Used for Grade Standards. Text. Res. Jour., 20, 277-78, 1950.

A report of Shirley Analyzer nonlint content of bales used in grade standards.

(24) Nickerson, Dorothy
Color Measurements of Cotton—Second Report on Application of Nickerson-Hunter Cotton Colorimeter, Including a Discussion of Recent Work on Standards for Grade. U. S. Dept. Agr., PMA, Mar. 1953. 38 pp.

Report prepared for use at 1953 grade standards conference. Includes details regarding preparation of 1953 grade standards not available elsewhere; color change expected for cotton under storage; degree of color variation in uniform bales selected for standards, trash measurements on standards bales, etc.

(25) Nickerson, Dorothy
Color of Cotton Grade Standards, 1909-54. U. S. Dept. Agr., AMS, Apr. 1954. 15 pp.

Color measurements of grade standards, 1909 to 1954, stored in Cotton Division vaults. These include old Liverpool standards.

(26) Nickerson, Dorothy
Color Measurement Data Relating to Grade Standards for Cotton and Cotton Linters. U. S. Dept. Agr., AMS, May 1956. 52 pp.

A report prepared for use at 1956 conference, containing 44 diagrams and 2 tables, showing the progress of cotton color measurements applied to preparation and maintenance of standards.

(27) Nickerson, D., and Tomaszewski, J. J.
Color Measurements of Grade Standards, 1952-1959. U. S. Dept. Agr., AMS, May 1959. 7 pp.

No. 1 of 4 reports prepared for use at 1959 Grade Standards Conference. Contains color measurements on cotton grade standards.

(28) Nickerson, D., and Tomaszewski, J. J.
Summary of Color Measurements from Surveys of Cottons Classed in 8 Crop Years, 1951 to 1958. U. S. Dept. Agr., AMS, May 1959. 13 pp.

No. 2 of 4 reports prepared for use at 1959 Grade Standards Conference. Contains color measurements of cottons classed in grade surveys, 1951-1958.

(29) Nickerson, D., Tomaszewski, J. J., and Newton, F. E.
Trash and Color. U. S. Dept. Agr., AMS, May 1959. 16 pp.

No. 3 of 4 reports prepared for use at 1959 Grade Standards Conference. Contains diagrams and tables relating to trash content and color of cottons.

(30) Nickerson, D., and Tomaszewski, J. J.
Color Change in Storage. U. S. Dept. Agr., AMS, May 1959. 17 pp.

No. 4 of 4 reports prepared for use at 1959 Grade Standards Conference. Contains report of 1956 grade standards stored 3 years under several conditions of temperature and humidity. Includes reprint of 1958 Text. Inst. Jour. report.

(31) Nickerson, Dorothy
Cotton Colorimeter—An Aid in Extending Knowledge of Cotton Quality. A report to Open House of American Cotton Manufacturers Institute, Inc., Clemson, S. C., May 4, 1960. U. S. Dept. Agr., AMS, May 1960. 15 pp.

A description of the Nickerson-Hunter Cotton Colorimeter (both Gardner and Spinlab models) and a discussion of its applications.

(32) Nickerson, Dorothy
Recent Trends in Trash Content of Raw Cotton Create a Problem in Grade Standards. U. S. Dept. Agr., AMS-454, Feb. 1962. 15 pp.

Color and trash measurements of cottons, showing need for change in cotton grade standards to take account of reduction in amount of trash in recent crops. The relationship of color and trash in cotton of present crops no longer matches that of the standards.

(33) Nickerson, D., Newton, F. E., and Fry, E. G.
Cotton Quality Relationships Between Selected Measures of Quality and Fiber, Yarn, and Processing Properties. U. S. Dept. Agr. AIB 257, 137 pp., 59 tables; and Supplement, 248 pp., 117 tables. Apr. 1962.

Includes statistical summary of cotton quality relationships for cottons in 1946-60 surveys, and six studies based on bales used in grade and staple standards during 1956-1960: 62 white and 68 colored grade bales studied in 1956, 181 grade and 144 staple bales in 1959, and 115 grade bales, 33 staple bales in 1960. Multiple correlations are reported in the main report, simple correlations are reported in the Supplement.

(34) Overby, E. J.
Standards for United States Cotton. Address to American Standards Association 6th National Conference on Standards, Washington, D.C. Oct. 26, 1955. Mimeo. AMS, U. S. Dept. Agr. 17 pp.

(35) Overby, E. J.
Grade Standards for American Upland Cotton. Textile Forum, N. C. State College, Feb. 1960. pp. 8-9, 21-22.

A general report on U. S. grade standards, following the 1959 Universal Standards Conference.

(36) Palmer, A. W.
The Commercial Classification of American Cotton, With Reference to the Standards for Grade, Color, and Staple. U. S. Dept. Agr. Circ. 278, Jan. 1924. 35 pp., illus.

Discusses elements and purpose of cotton classification according to grade, staple, character, and in relation to value, effects of special conditions on value; sampling and handling of samples; light and weather conditions and their influence.

(37) Palmer, A. W.
The Growth of Cotton Fiber Science in the United States. Smithsonian Report for 1960, pp. 473-508. Publ. 4452, Smithsonian Institution, Washington, D. C., 1961.

Traces growth of cotton fiber science for past 50 years, relating it in particular to U.S.D.A. attack on problems of standards and their relation to quality descriptions begun in 1927 in the Cotton Division's laboratories under R. W. Webb. Reference list includes testing methods and apparatus in relatively wide use, or historically important.

(38) Pfeiffenberger, George W.
The Shirley Analyzer. Textile Research, XIV, 1944.

Describes Shirley Analyzer, developed at Shirley Institute, Manchester, England, as effective means for analysis of trash in cotton lint.

(39) Richardson, H. B., Bailey, T. L. W., Jr., and Conrad, Carl M.
Methods for the Measurement of Certain Character Properties of Raw Cotton. U. S. Dept. Agr. Tech. Bull. 545, 1937. 76 pp., illus.

(40) Smith, H. R.
A New Cotton Trashmeter. A report to 1960 Cotton Research Clinic, Asheville, N. C., May 31, 1960. U. S. Dept. Agr., AMS, May 1960. 10 pp.

A description and evaluation of the Cotton Trashmeter (an optical electronic scanner), developed by Outlook Engineering Corporation for the Cotton Division to measure trash content on the surface of cotton.

(41) Smith, H. R.
Where We Are in Measuring Color and Trash. A report to 1961 Cotton Research Clinic, Memphis, Tenn., May 16, 1961. U. S. Dept. Agr., AMS, May 1961. 8 pp.

1961 status of work in measurement of color and trash in cotton, particularly in regard to available instruments.

(42) Smith, Harvin R., and Thigpen, Maurice E.
Relationship of Low Range Micronaire Readings to Cotton Processing Performance and Fiber Properties. U. S. Dept. Agr., AMS, Aug. 1962. 10 pp.

(43) Smith, W. S.
Air Gauge Measures Fiber Fineness. Textile Industries, III, 86, Nov. 1947.

First description of Micronaire development in laboratories of West Point Mfg. Co. on basis of Sheffield's Precisionaire adapted to cotton about 1944.

(44) U. S. Congress, 69th
Grade and Staple Statistics Act, 1927. Public Law 740, appr. Mar. 3. 44 Stat. 1372: 7 U.S.C. 471-476.

(45) U. S. Department of Agriculture
Establishment and Promulgation of Official Cotton Standards of the United States. S.R.A.-Markets 1,[4] Jan. 19, 1915. 11 pp.

Replacement of 1909 permissive standards by 1914 standards discussed, and preparation, establishment and promulgation of 1914 standards, their price and distribution.

(46) U. S. Department of Agriculture
Determination of Disputes and Questions Other Than Grade Arising in Connection With the Fifth Subdivision of Sec. 5 of the U. S. Cotton Futures Act. S.R.A.-Markets 2, Jan. 1915. pp. 13-15.

(47) U. S. Department of Agriculture
____________. S.R.A.-Markets 3, Mar. 3, 1915. 6 pp.

Rules and regulations under the U. S. Cotton Futures Act of 1914. Includes opinions of general interest regarding questions arising under the Act.

---

[4] Service and Regulatory Announcements; Office of Markets and Rural Organization.

(48) U. S. Department of Agriculture
______________. S.R.A.-Markets 4, Apr. 16, 1915. pp. 23-49.

Explains specific rules and regulations under Cotton Futures Act and contains correspondence and opinions of general interest regarding questions under the Act.

(49) U. S. Department of Agriculture
______________. S.R.A.-Markets 5, Aug. 11, 1915. pp. 51-80.

Address by the U.S.D.A. Solicitor explaining the U. S. Cotton Futures Act. Includes opinions regarding questions arising under the Act.

(50) U. S. Department of Agriculture
The Official Cotton Standards of the United States. S.R.A.-Markets 6, Jan. 24, 1916. 32 pp.

Provides details of development, preparation, and distribution of official standards. Includes specifications for grading rooms equipped with skylight, details of experiment storing standards in vacuum containers, lists holders of standards.

(51) U. S. Department of Agriculture
Brief History of the Movement to Secure Universal Cotton Standards. S.R.A.-Markets 7, Mar. 17, 1916. pp. 33-50.

Review, 1801 to 1916. Includes details of visits and correspondence of U. S. representatives (W. R. Meadows and W. P. Barbot) with leading European exchanges and associations, also photographs of grade boxes, and of standards in vacuum cells.

(52) U. S. Department of Agriculture
______________. S.R.A.-Markets 8, Apr. 15, 1916. pp. 51-95.

Discusses proper means of identifying cotton involved in disputes, and determination and record of disputes under U. S. Cotton Futures Act.

(53) U. S. Department of Agriculture
______________. S.R.A.-Markets 9, Apr. 29, 1916. pp. 97-117.

Review of provisions of pending Futures bill, with amendments. Official standards established for Yellow Tinged, Yellow Stained, and Blue Stained cottons.

(54) U. S. Department of Agriculture
______________. S.R.A.-Markets 10, Sept. 1, 1916. pp. 119-134.

Changes in United States Cotton Futures Act by re-enactment August 11, 1916. Untenderable cotton defined; re-establishment of 1914 official standards announced. Forms included for purchase of standards.

(55) U. S. Department of Agriculture
______________. S.R.A.-Markets 16, Dec. 16, 1916. 15 pp.

Information regarding handling disputes under amended U. S. Cotton Futures Act. Includes list of standards inspected and canceled (fading of spots in lower grades the most frequent cause of cancellation). Lists designated spot markets adopting U. S. official standards; Rotterdam adopted standards. Comparison included of U. S. and Liverpool standards.

(56) U. S. Department of Agriculture
______________. S.R.A.-Markets 41,[5] Jan. 20, 1919. 16 pp.

Contains public notice establishing official standards for American Egyptian and Sea Island cottons and for length of staple. Includes detailed description of method of pulling staple, with pictures.

(57) U. S. Department of Agriculture
<u>Regulations Under Section 5 of U. S. Cotton Futures Act as Amended March 4, 1919</u>. Office of Secretary, Circ. No. 137, May 1919. 23 pp.

(58) U. S. Department of Agriculture
<u>Regulations for Cotton Warehouses Under the United States Warehouse Act</u>. Office of Secretary, Circ. 143, Oct. 1919. 41 pp.

Act of August 11, 1916, as amended July 24, 1919, revised regulations approved Sept. 15, 1919. Regulation 8 concerning cotton classification, contains definitions of irregularities or defects relating to cotton packaging or quality. Regulation 9 concerns cotton appeals. The Warehouse Act is quotedin full, pp. 31-36.

(59) U. S. Department of Agriculture
<u>Universal Standards for American Cotton, With a Brief History of the Movement to Secure Universal Cotton Standards</u>. Sept. 1922. 34 pp.

Review of history to obtain cotton standards, 1801 to 1921, a bound mimeographed report in English, French, and German, made available by U. S. Department of Agriculture.

---

5 Bureau of Markets.

(60) U. S. Department of Agriculture
______________. S.R.A.-BAE 72, Oct. 1922. 15 pp.

Brief history of establishment and replacement of official standards; 1923 revision of standards, first since August 12, 1916 (when Cotton Futures Act was re-enacted), includes provision for descriptive grades for Gray, Spotted, and Light Stained grades. Provides table illustrating numerical and descriptive nomenclature for relating grades represented by descriptive and physical standards. Includes text of 1922 notice establishing standards.

(61) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Standards Act. S.R.A.-BAE 80, July 1923. 21 pp.

Regulations effective August 1, 1923.

(62) U. S. Department of Agriculture
The United States Cotton Standards Act and the Universal Standards. S.R.A.-BAE 82, Mar. 1924. 28 pp.

Discusses essential provisions of the Act, and details of conferences on both grade and staple standards and their required use, held with American and European groups prior to acceptance of American standards as Universal standards. Standards promulgated under the Cotton Standards Act are listed for American upland, American Egyptian, Sea Island, and for lengths of staple; includes text of the Cotton Standards Act.

(63) U. S. Department of Agriculture
Standards for Cotton Classification in the United States and Abroad. S.R.A.-BAE 92, Aug. 1925. 23 pp.

Lists essential provisions of U. S. Cotton Standards Act and regulations, and official standards for grade of American upland and American Egyptian, length of staple, and cotton linters. Includes discussion of formal action of European exchanges in adopting the standards for grade as Universal Standards, sustainment by the Attorney General of the action of the Department of Agriculture in entering into agreements with the European associations, reports of the 1925 meetings (March in Washington, May in London), a copy of agreements between U.S.D.A. and European associations relating to use of the official standards, and text of the Cotton Standards Act.

(64) U. S. Department of Agriculture
Official Standards of the United States for American Cotton Linters. S.R.A.-BAE 94, June 26, 1925. 9 pp.

Linters standards, their promulgation, description, and a history of American cotton linters by G. S. Meloy.

(65) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Standards Act. S.R.A.-BAE 95, Aug. 1, 1925. 27 pp.

Includes definitions and regulations concerning classification, submission of samples, certification under Forms A, B, and C, reviews and appeals, licensed classifiers, official cotton standards, fees and costs, American cotton linters, adjustment of disputes arising from contracts for shipment of cotton from the United States.

(66) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Futures Act. S.R.A.-BAE 105, May 15, 1927. 27 pp.

Regulations of the Futures Act, as amended, list of the current spot markets, current official standards for grade and staple, and text of the Futures Act.

(67) U. S. Department of Agriculture
Items Relating to the Administration of the United States Cotton Futures and Cotton Standards Acts. S.R.A.-BAE 109, Jan. 1928. 13 pp.

Extra White standards established; Cotton Futures Act amendments of February 1927; 1926 London conference on staple standards; 1927 Universal Standards Conference; standards for color of linters; letters of interest; text of act authorizing collection of grade and staple length statistics.

(68) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Standards Act. S.R.A.-BAE 115, Oct. 1, 1928. 24 pp.

Information pertaining to administration of the act, submission of samples, classification, issuance of certificates, reviews, and fees.

(69) U. S. Department of Agriculture
Proceedings of International Universal Cotton Standards Conference of 1929 and Items Relating to the Administration of the United States Cotton Futures and Cotton Standards Acts. S.R.A.-BAE 117, Nov. 1929. 23 pp.

Discussion and correspondence relating to proceedings of 1929 conference; revision of American Egyptian and Extra White standards; tentative standards for preparation of long staple cotton; 1928 revision of staple standards; opinions and letters; text of Act relating to investigation of new uses for cotton.

(70) U. S. Department of Agriculture
<u>Regulations of the Secretary of Agriculture Under the United States Cotton Futures Act</u>. S.R.A.-BAE 124, May 1931. 22 pp.

Regulations pertaining to definitions, inspection and samples, classification, certificates, fees, spot markets, price quotations and differences, and official standards; includes text of Cotton Futures Act.

(71) U. S. Department of Agriculture
<u>Regulations of the Secretary of Agriculture Under the United States Cotton Standards Act</u>. S.R.A.-BAE 125, May 1931. 23 pp.

Rulings effective May 1, 1931, pertaining to classification requests, submission of samples for Form A, B, and C determinations, reviews and licensed classers, current U. S. cotton standards, and American cotton linters.

(72) U. S. Department of Agriculture
<u>International Universal Cotton Standards Conference of 1933</u>. BAE, mimeo. 36 pp.

Verbatim report of meeting of U.S.D.A. with American delegates held on afternoon of March 13, 1933, prior to a meeting of the 1933 conference under the principal standards agreement.

(73) U. S. Department of Agriculture
<u>Items Relating to the Administration of the United States Cotton Standards and Cotton Futures Acts</u>. S.R.A.-BAE 146, Sept. 1934. 21 pp.

Licensing of cotton samplers; proceedings of 1931 and 1933 conferences; revision of Extra White standards; half grades for American Egyptian cotton; amendments to staple standards; preparation standards for long staple cottons; provision for licensing additional classers; letters.

(74) U. S. Department of Agriculture
<u>Proposed Revisions of the Universal Standards for Grades of American Upland Cotton</u>. BAE, mimeo., 1935. 18 pp.

A report circulated to representatives of cooperating cotton industry, discussing the need for changes in grade standards, and results of laboratory and classification studies and surveys on which recommendations are made.

(75) U. S. Department of Agriculture
<u>International Universal Cotton Standards Conference of 1936</u>. BAE, mimeo., 1936. 19 pp.

Verbatim report of general meetings held March 9 and 12, 1936, under Universal Cotton Standards Agreement, with list of those attending.

(76) U. S. Department of Agriculture
Revision of Standards for Grades of American Upland Cotton. S.R.A.-BAE 150, Mar. 1936. 10 pp.

1935 revision of standards, effective August 20, 1936; classification according to the new standards; public notice establishing and listing revised standards; list of those attending 1935 conference.

(77) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Futures Act. S.R.A.-BAE 152, Aug. 1936. 22 pp.

Regulations under the futures act pertaining to cotton classification, reviews, fees, price quotations, spot markets; current official cotton standards are defined.

(78) U. S. Department of Agriculture
Regulations of the Secretary of Agriculture Under the United States Cotton Standards Act. S.R.A.-BAE 153, Aug. 1936. 26 pp.

Regulations relating to classification requests; submission of samples; Form A, B, and C certificates; reviews; licensed samplers and classers; current official standards; settlement of disputes; etc.

(79) U. S. Department of Agriculture
Developments in Cotton Standardization and Related Services. S.R.A.-AMA 163,[6] Aug. 1942. 26 pp.

Proceedings of the 1936 and 1939 conferences, Supplemental Agreement B relating to Universal Standards for American cotton; revision of Sea Island and American Egyptian standards; staple standards in effect 1942; preparation standards for long staple cottons made permissive; symbols listed for grade designations; classing and market news services, and cotton-fiber testing service established under special legislation.

(80) U. S. Department of Agriculture
Development and Use of Standards for Grade, Color, and Character of American Cotton Linters. PMA, July 1946, mimeo. 17 pp.

A description of the establishment, use, and characteristics of linters and United States Linters Standards.

---

[6] Agricultural Marketing Administration.

(81) U. S. Department of Agriculture
Further Developments in Cotton Standardization and Related Activities. S.R.A.-PMA 165, Nov. 1947. 35 pp.

Contains proceedings of 1946 Universal Cotton Standards Conference, a list of the U. S. American upland cotton standards as revised, effective August 1, 1947; list of current official standards for American Egyptian, Sea Island, length of staple, linters, and cottonseed; includes text of the Universal Standards Agreement.

(82) U. S. Department of Agriculture
Universal Cotton Standards Conference of 1950. PMA, mimeo., 1950. 20 + 6 pp.

Proceedings of 1950 conference held to examine and approve copies of the original 1946 standards for American upland cotton; agreement made that in preparing for next conference, consideration would be given to revision of standards and preparation of physical standards for Spotted and Gray cottons. The Department will make careful surveys of crop on which to base any revision.

(83) U. S. Department of Agriculture
American Egyptian Grade Standards Meeting of 1951. PMA, Cotton Branch, June 25, 1951. 18 pp.

Proceedings of the 1951 meeting, at which revised standards were approved to represent the color of current crops. Production of American Egyptian cotton by grades, since 1942, are included, also a brief history of American Egyptian standards, and pertinent correspondence.

(84) U. S. Department of Agriculture
Proposed Rule Making. Federal Register, June 7, 1952, p. 5195.

Notice of proposed revision of cotton grade standards, and of public meeting to be held June 19, 1952 in Washington classing laboratory where proposed standards will be on display. Before adoption, standards must be approved by signatories to Universal Cotton Standards Agreements.

(85) U. S. Department of Agriculture
Official Cotton Standards of the United States for the Grade of American Upland Cotton, Effective August 15, 1953. Federal Register, Aug. 15, 1952, Title 7, Sec. 27, pp. 7405,7,8.

Following meetings held in Washington, D. C., June 19, 1952, and in Le Havre, France, July 17, 1952, new standards were promulgated, 24 grades as listed, effective August 15, 1953.

(86) U. S. Department of Agriculture
Universal Cotton Standards Conference of 1953. PMA, 1953. 37 + 28 pp.

Proceedings of 1953 conference, which examined and approved copies of standards promulgated the previous August, to be effective August 15, 1953. The proposal to make Good Middling a physical grade was approved, and it was promulgated July 21, 1953, to become effective August 1, 1954.

(87) U. S. Department of Agriculture
Universal Cotton Standards Conference for Good Middling, 1954. AMS, June 7, 1954. 14 pp.

Proceedings of the 1954 Good Middling Conference which was held to approve key sets of the original Good Middling standard that had been approved at the 1953 conference.

(88) U. S. Department of Agriculture
Cotton Testing Service: Tests Available, Equipment and Techniques, and Basis for Interpreting Results. AMS-16, revised Dec. 1963. 55 pp.

Describes various cotton fiber and manufacturing tests available on a fee basis under the Cotton Testing Service Act (7 U.S.C. 473d), the methods employed in making the tests, and the significance of test results.

(89) U. S. Department of Agriculture
Regulations of the Department of Agriculture for Cotton Classification and Market News Services for Organized Groups of Producers. S.R.A.-AMS 173, Apr. 1956. 6 pp.

Regulations concerning classification and market news services, sampling and classification instructions; text of Smith-Doxey Amendment.

(90) U. S. Department of Agriculture
Universal Cotton Standards Conference of 1956, May 21-23. AMS, 1956. 45 pp.

Proceedings of 1956 conference: copies of standards examined and approved; field trial boxes for Spotted cottons continued; descriptive standard for Strict Good Middling approved; validity period of grade standards reduced to 12 months. Includes text of February 16, 1956 revision of Universal Cotton Standards Agreements.

(91) U. S. Department of Agriculture
American Egyptian Grade Standards Meetings of 1956, May 23. AMS, 1956. 16 pp.

Revision of standards in effect since 1951 proposed at May 23 meeting but no agreement reached. Revision reconsidered and approved at a meeting on June 5.

(92) U. S. Department of Agriculture
Revised Official Grade Standards for American Egyptian Cotton. Federal Register, Title 7, Ch. 1, Part 27, July 3, 1956.

Effective August 1, 1957, standards for nine grades in physical form, Nos. 1-9, promulgated as revised American Egyptian standards, a descriptive Grade 10 to cover cotton inferior to Grade 9.

(93) U. S. Department of Agriculture
The Classification of Cotton. AMS Misc. Publ. No. 310, June 1956. 56 pp.

A handbook containing general information pertaining to the classification of cotton, originally published 1938, replacing U.S.D.A. Circ. 278; revision in preparation.

(94) U. S. Department of Agriculture
Regulations of the Department of Agriculture for Cotton Classification Under Cotton Futures Legislation. S.R.A.-AMS 175, Oct. 1956. 26 pp.

Administration of regulations, inspection of sampling, sampling, classification and micronaire determinations, cotton classing certificates, are major items.

(95) U. S. Department of Agriculture
Regulations of the Department of Agriculture Governing Cottonseed Sold or Offered for Sale for Crushing Purposes (Inspection, Sampling, and Certification). S.R.A.-AMS 174, Revised Apr. 1958. 12 pp. (Amendment Sheet 1, November 1958.)

Regulations concern licensing of cottonseed chemists and samplers; fees and costs. Amendment Sheet 1 concerns 1958 changes in fees.

(96) U. S. Department of Agriculture
Standards for Grades of Cottonseed Sold or Offered for Sale for Crushing Purposes Within the United States. S.R.A.-AMS 179, Apr. 1958. 4 pp. (Amendment Sheet 1, August 1962.)

Includes method for determination of grade, quantity and quality index, sampling, analysis and certification of samples and grades, and quotes provision of Agricultural Marketing Act of 1946, as amended. Amendment Sheet 1 concerns 1962 changes in premiums and discounts.

(97) U. S. Department of Agriculture
Cotton and Cotton Linters Standards. S.R.A.-AMS 180, Dec. 1958. 17 pp.

Includes a list of 1958 cotton standards for: American upland; American Egyptian; Sea Island; length of staple; linters; and fiber fineness and maturity under Cotton Futures Act.

(98) U. S. Department of Agriculture
Universal Cotton Standards Conference of 1959, May 25-27. AMS, 1959. 64 pp.

Proceedings of the 1959 conference held to approve new key sets of 1953 standards. Revision of standards discussed, but most of groups were opposed. Official physical standards for Spotted cottons, Strict Middling through Low Middling, were approved, Good Middling Spotted to remain descriptive. Descriptive standards for plus cotton in the White grades, for Light Spotted, Gray, and Light Gray were approved.

(99) U. S. Department of Agriculture
Amended Official Cotton Standards of the United States for the Grade of American Upland Cotton (Universal Standards) Effective August 1, 1960. S.R.A.-AMS 180, Amendment Sheet 1, July 1, 1959.

A 3-page reprint from Federal Register of June 25, 1959, Title 7, Sec. 28, listing amended grade standards effective August 1, 1960, and including a listing of the changes incorporated into the standards.

(100) U. S. Department of Agriculture
Cotton and Cotton Linters Standards. S.R.A.-AMS 180, Amendment Sheet 2, August 1, 1960.

Amendment to Section 28.303 re standards for length of staple, change in tenderable grades, etc.

(101) U. S. Department of Agriculture
Compilation of Statutes Relating to Research, Statistics, and Reports, Service and Regulatory Work, and Food Distribution, as of Jan. 1, 1961. AMS, Agr. Handbook No. 201, Sept. 1961. 269 pp. Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C. 75 cents.

Contains brief description and references to statutes under which U.S.D.A. operates, including general and specific references to cotton; e.g., cotton statistics estimates, Cotton Futures Act, Cotton Standards Act, etc. Included are references to all changes, amendments, and related laws.

(102) U. S. Department of Agriculture
Universal Cotton Standards Conference of 1962, May 24-25. AMS, 1962. 39 pp.

Proceedings of 1962 conference held to examine and approve key sets of copies of the Universal Cotton Standards, and to consider a proposed revision of the 1953 standards.

(103) U. S. Department of Agriculture
Cotton Grade Standards Meetings. Two vols. of reports re meetings 1933 to 1962, filed in ring binders in Standardization Section.

These contain mimeographed and typed reports of meetings, and of correspondence, some not available in published form, e.g., for 1951-52 meetings re revision of standards.

(104) U. S. Department of Agriculture
International Cotton Calibration Standards Program. AMS, Revised 1963. 15 pp.

Describes the purpose, functions, and organization of the International Cotton Calibration Standards Program established Oct.-Nov. 1956.

(105) Webb, R. W.
The Suter-Webb Cotton Fiber Duplex Sorter and the Resulting Method of Length-Variability Measurements. Proc. Amer. Soc. Testing Materials, 32, II, 11 pp., illus.

Original description of Suter-Webb sorter.

(106) Whitaker, Rodney
Comments on the Adequacy, Reproduction, Application and Properties of the United States Official Standards for Staple Length. A report to Open House of American Cotton Manufacturers Institute, Inc., Clemson College, S.C., May 7, 1958. U. S. Dept. Agr., Cotton Div. 12 pp.

Covers discussion of staple standards and related statistical data.

(107) Whitten, M. E., and Webb, H. R.
The Standardization of Cotton Linters. AMS 251, July 1958. 32 pp.

A history of linters standards, including references to proceedings of 1954, 1955, and 1956 Linters Conferences. Includes references to test methods and surveys applied to development and production of linters standards for both grade and staple.

(108) Willis, H. H.
Manufacturing Tests of Cotton of White Grades of Universal Standards for American Cotton. U. S. Dept. Agr. Bull. 1488, Apr. 1927. 29 pp., 12 tables, 9 figs.

Tests of manufacturing properties reported for waste, working qualities, strength, bleaching and dyeing qualities of yarn and cloth made from each of nine grades of 7/8-1 inch staple representing upland cottons grown east and west of the Mississippi, each lot made of equal portions from three bales used in preparing standards.

(109) Yang, Hsien-Tong
Development of the United States Cotton Standards. Thesis, Cornell University, June 1937. Typed, illus. 197 pp.

Focuses attention on three major steps: permissive standards of 1909; the Cotton Futures Act of 1916, with its compulsory standards for futures trading; and the Cotton Standards Act of 1923, with compulsory standards for all cotton transactions, both spot and futures.

Index [1]

[1] Chronological

1964 A.S.T.M.
METHOD OF TEST FOR COLOR OF RAW COTTON USING
THE NICKERSON-HUNTER COTTON COLORIMETER.
(D2253-64T.) (June)

TO BE INSERTED

Preprint, 1964 I.E.S. TECHNICAL CONFERENCE,
Miami, Florida, August 31-September 3.

COLOR RENDERING OF LIGHT SOURCES: CIE METHOD OF SPECIFICATION AND ITS APPLICATION

By Dorothy Nickerson, 1/ and Charles W. Jerome 2/

This report is in two parts. Part I presents a method for rating lamps for color rendering properties that has been officially adopted (in process, June 1964) by the CIE on the basis of recommendations for an index based on a "test-color method." It points out the relation of the CIE to the IES method (July 1962 IE), and provides a working text and formulas. Part II discusses the meaning of the index, how it can be used, and shows applications to a wide variety of lamps.

I. CIE METHOD OF SPECIFYING COLOR RENDERING PROPERTIES OF LIGHT SOURCES

In the 25 years since the advent of the fluorescent lamp, studies of quality of lighting are fast catching up on studies of quantity of lighting (1).3/ Until quantity was available, that is, plenty of lumens-per-watt, not much could be done about quality, particularly about spectral quality. Use was made of whatever was available: the candle, gas flame, Welsbach mantle, then electric incandescent lamps. Tungsten, with a melting point at 3655K, permits satisfactory operating temperatures in the range of 2800K-3000K for 60- to 500-watt lamps, and it is fortunate

---

1/ Research color technologist, U. S. Department of Agriculture, Washington, D. C.; chairman, subcommittee on Color Rendering of Light Sources, IES Light Sources Committee.

2/ Sylvania Lighting Products, Inc., Salem, Mass.; member, subcommittee on Color Rendering of Light Sources, IES Light Sources Committee.

3/ Underscored figures in parentheses refer to Literature Cited.

Preprinted by U.S. DEPARTMENT OF AGRICULTURE, Agricultural Marketing Service, Market Quality Research Division, June 1964.

that in the visible range the spectral characteristics of incandescent tungsten closely parallel those of a black body radiator. This means that the color rendering properties of a tungsten filament lamp are generally similar to those of a black body radiator of approximately the same temperature.

With the advent of fluorescent lamps in 1939, the efficiency of lamps increased from about 13 to 17 lumens-per-watt for the ordinary incandescent lamps until today they are as high as 80 lumens-per-watt for standard fluorescent lamps. To improve the color rendering properties of fluorescent lamps a balance must be struck between quantity and quality of illumination. In this country, because of what has come to be accepted as public demand, more emphasis has been placed on lumens-per-watt than on color rendering, while on the European continent relatively greater emphasis has been placed on the color rendering properties of light sources.

Studies in color rendering have been hindered by lack of an index or specification that would provide as direct and simple a rating for the color quality of lighting as the specification of "lumens-per-watt" provides for quantity of lighting. Thus it is good news that the International Commission on Illumination (CIE)[4/] in 1964 has approved (in process, June 1964) the recommendation of its Expert Committee E-1.3.2 (color rendering) for a CIE Method of Measuring and Specifying Color Rendering Properties of Light Sources.

This CIE Test-Color Method provides for rating a lamp in terms of a color rendering index. This index, R, is based on the degree of

---

4/ CIE: official abbreviation for Commission Internationale d'Eclairage.

colorimetric shift of a test object under a test lamp in comparison to its color under a standard lamp of the same, or nearly the same, chromaticity. The rating consists of a General Index, based on a set of eight test-color samples, that may be supplemented by Special Indices, based on special-purpose test samples.

It has been agreed that this method be considered fundamental for appraisal of color rendering properties of light sources and be recommended for type designing as well as for testing individual lamps. It is also agreed that supplementary or abridged methods for routine measurements on individual lamps may be used when they provide results that agree with the recommended Test-Color Method. The specification applies to most general purpose illuminants of natural and artificial types.

A news note and brief description of the method that appeared in IE, January 1964 (2), points out that the CIE General Index is identical with the rating provided by the IES Interim Method of Measuring and Specifying Color Rendering of Light Sources, as approved by IES Council April 1962 (3), and that the Special Indices take into consideration German, Netherlands, and Japanese proposals for extending the use of the color-difference vector method to three instead of two dimensions.

A lamp with an index of 100 is one with color rendering properties identical to those of the standard reference lamp; a lamp with an index of 50 has color rendering properties that on the average shift the colors of objects about as much as they are shifted by a standard fluorescent white lamp at 3000K (such as was used in IES subcommittee studies) in comparison to the colors of the same objects under an incandescent reference lamp at 3000K. Indices below 50 indicate lamps under which the colorimetric shift is relatively greater than this.

Working Text and Formulas

The text of the CIE method consists of five sections. The first three—purpose, scope, and rating—are summarized above. Sections 4 and 5 cover rating procedures and calculations. These are summarized in the following section, with sufficient detail to provide an understanding of both General and Special Indices and sufficient references and data to complete the calculations. Discussion and background for much of this work, and several necessary tables, will be found in references (1, 2, 3), particularly in (3). Formulas and notations in the following section are those used in the CIE recommendation, and the paragraphs, greatly condensed, are numbered to conform with the CIE text.

4. Rating Procedure

4.1 General. To apply the test-color method the colorimetric shifts of suitably chosen test colors must be calculated. CIE tristimulus values of the test colors must be determined for both the light source to be tested and the reference illuminant. The next step is to transform these values into coordinates of the 1960 CIE uniform-chromaticity diagram. A correction is then applied for the difference in chromaticity coordinates between the two light sources, and the colorimetric shift is calculated from these corrected coordinates. As long as the differences between the test and reference source are kept small, this adjustment may be considered a satisfactory approximation for chromatic adaptation. In the ultimate version of the test-color method wider differences between lamps must be considered, and it will be necessary then that chromatic adaptation receive a more rigorous treatment.

4.2 Reference Illuminant. Unless otherwise specified, the reference for light sources with correlated color temperature 6000K or below

shall be a Planckian radiator at the nearest color temperature, and above 6000K the Abbot-Gibson series of spectral energy distributions of skylight.

Italics Note 1. The Abbot-Gibson series shall serve until such time as CIE E-1.3.1 recommends a one-dimensional series of relative energy curves for various phases of daylight, at which time such series shall replace the Abbot-Gibson series above 5000K.

4.3 Tolerances for Reference Illuminant. The reference illuminant is intended to be of the same or nearly the same chromaticity as the lamp to be tested. A tolerance of 5 mireds is suggested as a practical limit of difference. This corresponds to about 50K at 3000K, increasing to about 250K at 7400K. If the chromatic difference between test and reference illuminant is greater than this tolerance in any direction, the resulting color rendering indices may be expected to become less accurate.

Italics Note 2. Table XIV of (3) provides an example for computing these differences that is similar to the example in CIE Table 4 that concerns computation of the General Index; it does not include an example for computing Special Indices.

Italics Note 3. This tolerance specification makes it practical to supply a table of reference illuminants, from CIE A at 2854K to color temperatures of 14,000K up to ∞, included in the CIE report as Table 3. Similar data are contained in Appendix II of (3), with the exception that in the CIE table the Y data are converted to W (see section 4.4). Samples in (3) must be re-numbered in accord with the CIE-IES paired identification numbers listed in section 4.4.

4.4 Test-Color Samples. For calculating the General Color Rendering Index a set of eight Munsell test-color samples (T_i = 1...8) are used. These are selected to cover the hue circuit, are moderate in saturation, and approximately the same in lightness (Munsell value 6/ for daylight). For special purposes additional test-color samples (T_i, i . 8) may be used. Spectral reflectance data for samples 1...8, and for special samples 9...14 are listed in CIE tables.

Italics Note 4. The CIE tables are numbered 1 and 2; data for the same CIE samples are included in Table XIII of (3), under the following paired identification numbers:

CIE No.	IES No.	Munsell Notation		Munsell Prod.No.	CIE No.	IES No.	Munsell Notation		Munsell Prod.No.
1	47	7.5R	6/4	4277	9	58	4.5R	4/13	4785
2	48	5Y	6/4	6329	10	60	5Y	8/10	4991
3	50	5GY	6/8	4385	11	62	4.5G	5/8	3943
4	51	2.5G	6/6	6212	12	64	3PB	3/11	2312
5	69	10BG	6/4	4881	13	59	5YR	8/4	6324
6	53	5PB	6/8	4892	14	61	5GY	4/4	6157
7	54	2.5P	6/8	3837					
8	56	10P	6/8	6432					

In the CIE tables values are interpolated at the wavelengths of the mercury lines, and the Y data given in the IES report are adjusted by 2.5% to put them on an Absolute scale for reflectance. They are then reported in terms of the lightness index, W (see section 4.6).

4.5 Tristimulus Values for Colors of Test Samples. From a suitably accurate spectrophotometric measurement of the test lamp, combined with the spectral reflectance data given for the test sample, CIE (X,Y,Z)-tristimulus values or (x,y)-chromaticity coordinates shall be determined for the lamp and test sample. They shall be computed to a precision equal to four decimal places of (x,y). If direct measurements are used, they shall equal this precision.

4.6 Transformation into 1960 CIE-Uniform Chromaticity Scale Coordinates. The data of section 4.5 must now be transformed to the (u,v)-coordinates of the 1960 CIE-Uniform chromaticity scale diagram. For the General Index this is sufficient; for the Special Index, it is also necessary to transform the Y-data to the lightness index (W) recommended in 1963 (4) by E-1.3.1. These data must be computed to four decimal places, using the following formulas:

$$u = 4X/\ (X+15Y+3Z),\ \text{or}\ u = 4x/\ (-2x+12y+3)$$

$$v = 6Y/\ (X+15Y+3Z),\ \text{or}\ v = 6y/\ (-2x+12y+3)$$

$$W = 25Y^{\frac{1}{3}} - 17$$

5. Calculation of Color Rendering Indices

5.1 Designation. The color rendering index is designated by the letter R, the General Index by R_a, and the Special Index by R_i (i = 1,2,3... corresponding to the number of the test sample).

5.2 Calculation of General Color Rendering Index. This index may be read from a table (Table 5 of the CIE report, Table 1 of this report) or derived from the following equation on which this table is based:

$$R_a = 100 - 4.6\ \overline{\Delta E_a} \qquad [1]$$

$$\Delta E_a = 800\left\{[(u_{K,i} - u_K) - (u_{o,i} - u_o)]^2 + [(v_{K,i} - v_K) - (v_{o,i} - v_o)]^2\right\}^{\frac{1}{2}} \qquad [2]$$

and the average $\overline{\Delta E_a} = \dfrac{\Sigma \Delta E_a}{8}$

where:

$u_{K,i}$, $v_{K,i}$ are the UCS-coordinates of any test samples (index i) under the lamp to be tested (index K).

$u_{o,i}$, $v_{o,i}$ are the UCS-coordinates of any test samples (index i) under the reference illuminant (index o).

and

u_K , v_K are the UCS-coordinates of the lamp to be tested (index K).

u_o , v_o are the UCS-coordinates of the reference illuminant (index o).

Formula [2] can be written also as:

$$\Delta E_a = 800[(u_{o,i} - u'_{K,i})^2 + (v_{o,i} - v'_{K,i})^2]^{\frac{1}{2}} \qquad [2a]$$

where:

$$u'_{K,i} = u_{K,i} + (u_o - u_K)$$
$$v'_{K,i} = v_{K,i} + (v_o - v_K)$$

are the UCS-coordinates of any test sample (index i) after adjustment for $(u_o - u_K)$ and $(v_o - v_K)$.

Italics Note 5. Formula [1] is derived from

$$R_a = 100 - 3.7 \times 10^3 \, (\overline{\Delta E}_{u,v})$$

and $\Delta E_a = 800 \, \overline{\Delta E}_{u,v}$

in which $\overline{\Delta E}_{u,v}$ represents the average of the $\Delta E_{u,v}$ vectors for test samples 1 to 8 on the (u,v)-diagram, and $\overline{\Delta E}_a$ represents these same values after adjustment to provide a unit of color-difference that corresponds on the average to one NBS unit. (4)

The factor (3.7×10^3) converts the average vector lengths ($\Delta E_{u,v}$) under the IES 3000K standard fluorescent lamp to a rating of 50 when the reference illuminant is the incandescent lamp used in the IES committee work. The factor 800 applied to $\Delta E_{u,v}$ provides a unit of color-difference ΔE_a that is approximately the size of the NBS unit of color-difference, ΔE. This 800 (an approximation for 61 x 793) takes into account 61, the average W of the eight samples used in the General

Italics (Cont'd. Index, and the 13 which for standard conditions adjusts for the difference in size of W units of lightness and (u,v) units of chromaticity.

5.3 Calculation of Special Color Rendering Indices. Chromaticity differences for individual or special test-color samples may provide useful information in addition to a General Index, and for this purpose a Special Color Rendering Index may be derived that includes evaluation of any lightness difference that may occur. This Special Index R_i, based on ΔE_i, may be read from Table 1 of this report, or derived from the formula:

$$R_i = 100 - 4.6\ \Delta E_i \qquad [1a]$$

To obtain ΔE_i the following formula, which accords with the UCS color difference formula recommended in 1963 by E-1.3.1 (4), is applied. It is the general case of formula [2].

$$\Delta E_i = \Big\{ [W_{K,i} - W_{o,i}]^2 + 13^2 [W_{K,i}(u_{K,i} - u_K) - W_{o,i}\ (u_{o,i} - u_o)]^2 + 13^2 [W_{K,i}(v_{K,i} - v_K) - W_{o,i}\ (v_{o,i} - v_o)]^2 \Big\}^{\frac{1}{2}} \qquad [3]$$

Subscripts are the same as in section 5.2. Formula [1a] agrees with formula [1] when the lightness index W is 61, the same as that of test samples 1 to 8, and the differences in lightness index are zero. Under these conditions ΔE_i equals ΔE_a.

In its color rendering studies, the IES subcommittee did not find that inclusion of a lightness index sufficiently improved the ratings to warrant its use. The subcommittee is of the opinion that the General Index, particularly when accompanied by a listing of individual vectors for the eight samples on which R_a is based, will provide sufficient information for rating all but a very few special lamps.

For samples used in the General Index the difference between use of formulas [2] and [3] for ΔE_a and ΔE_i and for R and R_i is illustrated in Table 2 (Table 6 of the CIE report) for chromaticity levels of fluorescent lamps at about 3000K, 4300K, and 6500K. The 4300K and 6500K fluorescent lamps are special or European lamps. (During the IES subcommittee studies no generally available fluorescent tube was found on the American market with a color rendering index as high as is shown for these examples: deluxe Cool White lamps of three leading U.S. manufacturers, as measured by the IES subcommittee, had color rendering indices of 80 to 85; the daylight lamps were 76 to 78; only special color matching lamps were found over 90.) However, whether color rendering indices were high or low, the differences resulting from use of formulas [2] and [3] are uniformly small. When it is remembered that the unit for ΔE_a or ΔE_i is about the size of one NBS unit of color difference, it can be seen that the average difference reported for the lamps in Table 2 is no greater than 0.3 NBS unit, and only one of the individual test-color differences (Blue-green under the 4300K fluorescent lamp) is as large as 1.2 NBS units. The small differences between ratings obtained on a basis of formulas [2] and [3] support the IES subcommittee's recommendation for use of [2] in all but a few very special cases.

Another thing that can be learned on the basis of this comparison, and by reference to Table 1, is the relation and significance of the different units that are used. For example, it requires a vector difference of 0.00027-u,v units, or 0.22 NBS units, to make a 1-point change in R. Thus a change of 5 in R is roughly equal to one NBS unit of color difference. It follows that a rating of 90 indicates, in

comparison to a reference standard, that a lamp will duplicate the colors of objects within an average of about 2 NBS units of color difference, and for a lamp that rates 50, the colors of objects will be duplicated within an average of about 10 NBS units. Since in commercial color matching work tolerances tighter than one NBS unit are often required, the relative importance of a difference of 2 or 5 in R becomes apparent.

II. THE APPLICATION OF COLOR RENDERING INDICES

The color rendering index is still so new that only a very few people have a clear idea of what it is and how it may be used. The answer to the first of these questions is contained in the first part of this paper. In brief, the adoption of a series of reference illuminants contains the implicit assumption that under each reference lamp the colors of objects will appear as expected for a lamp of its chromaticity. And the color rendering index of a lamp gives a measure of how closely the colors of objects under a test lamp duplicate those of the same objects under the reference source. The index provides an average over all colors. That is, a lamp which distorts only one color badly may have the same index as another which distorts all colors slightly. However, in the process of determining the index the direction and amount of distortion of the individual colors are measured so this information is available and can be used although it cannot be contained in a single number index. This is somewhat analogous to determining chromaticity coordinates (x,y) from spectral energy distributions: an infinite number of distributions will give the same x and y, but the coordinates themselves cannot indicate which. However, just as chromaticity coordinates can be used to advantage in many ways, so the general color rendering

index, R_a, provides a useful piece of information. How it can best be used is still largely unknown or a matter of speculation. Its usefulness will grow as more experience is obtained with it and as more people gain a clearer understanding of its meaning. For example, it can be foreseen that sometime in the future we not only will have tables for the quantity of light needed for certain tasks or applications (See Fig. 2-25, IES Handbook, 3rd Ed.) and recommended color of illuminants, but also tables of recommended quality (color rendering index) of the illuminant for various applications. At this point, we do not have sufficient information or experience to do this except in a general way. It will require considerable research and observations before tolerance specifications can be set up intelligently. The first step in this direction is determining the color rendering indices of the various types of light sources. This is being done in the work of the IES Color Rendering Committee which already lists nearly 200 lamps for which color rendering indices have been determined, and by members of C.I.E. committee E-1.3.2, whose work in this field has been extensive.

For example, the chairman, W. Münch of Germany, has undertaken collection and measurement of fluorescent lamps representative of international manufacture, and another member, J. L. Ouweltjes of the Netherlands, has reported an extensive computer study (11) that includes 46 daylight, 53 white, and 65 warm white fluorescent lamps representing combinations of phosphors of types available now and probable in the future. These computed groups of lamps, each group color-matched for a given chromaticity, have been the basis for considerable study in developing the rating method, much of the data having been supplied the I.E.S. subcommittee for a check on various proposed rating methods. One early result of the Ouweltjes'

study demonstrated clearly the superiority of the test-color method over the spectral band method for assessing color rendering properties of a lamp, for in the band method the band divisions affect the rating critically.

Despite the imperfect state of this art, the color rendering index already has had useful applications both here and abroad. A recent one in this country has been in the development of the best color rendering available for daylight quality lamps. As Dr. Judd is reporting on this same program, in relation to the work of the CIE committee on colorimetry an intensive study of the spectral quality of daylight has recently been made, and it was desired that a fluorescent lamp be made to match the reported results as closely as possible for a given color temperature. The solution involved varying the various available component phosphors, keeping the chromaticity constant, and checking the effect on the color rendering index using this newly developed specification for daylight as the reference source. The goal is, of course, the combination which will give the highest index. The resulting SED for 6500K is shown in Figure 1, together with that of the reference source. The eight test colors under these sources are shown in the 1960 CIE-UCS diagram in Figure 2. The color rendering index of this lamp is 95 which is really quite good for a fluorescent lamp with its inherent discontinuities caused by the spectral lines of the mercury arc. An interesting innovation of this lamp is that it not only contains the visual quality of daylight, but also approximates its ultraviolet quality. Therefore, this is a single source which possibly can be used in the evaluation of daylight fluorescent colors which are so popular at the present time.

The color rendering index has also played a part in the development of the metallic halide lamp (5). In this, various additives to the arc were evaluated not only by their effect on electrical characteristics and lumen output of the lamp, but also by their effect on color and color rendering.

Possibly the greatest use to which the color rendering index wil be put immediately is in the evaluation of various short-cut or spectral band systems which have been proposed (6, 7, 8, 9, 10, 11). In the past, these systems have led to endless arguments with no possible definite conclusion since there was no criterion for judging when they gave a right or wrong answer. Now, as specifically stated in the CIE method, ". . . supplementary or abridged methods for routine measurements on individual lamps may be used when they provide results that agree with the recommended Test-Color Method."

Correlation studies between the CIE method and the band system proposed by Crawford (6) are shown in Figure 3. It will be noted that in general, fairly good correlation was obtained between the two systems for the limited number of lamps used in this study. More samples should be used in this study. More samples should be used before any definite conclusions are drawn, particularly lamps with color rendering indices between 20 and 60 so that the correlation line could be more accurately fixed. However, this illustrates the use of the color rendering index to evaluate another system. For example, assuming the correlation shown is valid, these results indicate that Crawford's Figure of Merit is less sensitive to color rendering differences at the high end (R over 80) than is the CIE system. This correlation may also indicate the precision of these measurements. It will be noted that if the FM is given ±50, all the

points would fall on the line. By the same token, if the R is given ±5, the points would also fall on the line. The important thing at this stage of the art is that such correlations can indicate the directions in which to move in order to improve the system's correlation with the CIE index.

In the CIE method, a limitation of 5 mireds is imposed on the color difference between the test lamp and the reference source. That is, this method officially is limited to lamps which lie quite close to the locus of black body radiations on the CIE Chromaticity Diagram. This is necessary because we do not yet fully understand how to incorporate chromatic adaptation into this method.

In many instances the real lamps used in this study are outside of this limitation as indicated by Δu and Δv (Table 3), greater than 0.0020. However, the results agree, at least qualitatively, with visual observations of the color shifts involved and the resulting indices, R_a, line up reasonably well with visual evaluations of the color rendering properties of the lamps.

In an effort to get some idea of the errors introduced by this unorthodox procedure, an investigation was made using the E-HI mercury lamp. Figure 4 shows the positions of our eight test colors on the (u,v)-diagram under this lamp and under the reference source. Since the radiation from the E-HI lamp consists almost entirely of monochromatic spectral lines, it is a fairly easy task to juggle their relative intensities to obtain a theoretical source which will exactly match the chromaticity of the reference source. This was done and in Figure 5 the positions of the eight test colors are shown under the reference source, under the real E-HI translated to make its chromaticity match that of

the reference source, and under the theoretical E-HI lamp. It will be noted that both qualitatively and quantitatively nearly the same results are obtained by translating the data as with the theoretical lamp. Also, the resulting color shifts agree well with the known visual appearance of these colors under the mercury arc. That is, the yellow is rendered much greener, the red much grayer, etc.

Similarly, the other lamps studied which require greater translations than that allowed for rigorous data show results which agree well with visual evaluations. Therefore, use of this procedure seems justified even though the absolute magnitude of the color rendering index may be less accurate.

So far, we have been discussing the faithful rendition of colors. Sometimes a light source is desired which distorts colors in a certain direction. An old example of this is the fluorescent soft white. This was purposely designed to suppress greens and enhance reds, i.e., a distortion of these colors so that red meats in butchers' show cases would appear redder and fresher than under ordinary fluorescent lamps.

A more recent example is Natural fluorescent whose spectral energy distribution is shown in Figure 6. Here again a deliberate distortion of colors has been introduced to enhance the appearance of human complexions. In these instances of deliberate distortions, our color rendering index has little or no significance. However, in the process of computing the index, the shifts of our test colors are determined (see Fig. 7) and these can be used to correlate with color preference studies (8).

Up to this point, areas of utility for the color rendering index have been pointed out and areas suggested in which we would like to have additional information. In the work of the Color Rendering Committee, some

interesting studies already have been made. For example, in a 1960 paper (1) spectral energy distributions and the colorimetric shifts of a series of test samples were shown for a series of the most popular fluorescent lamps made by the three largest manufacturers in this country. Color rendering indices for these lamps are listed in Table 4 together with the shifts for each of the eight test colors.

Lamps of each of the "Standard" colors, i.e., Warm White, White, Cool White and Daylight, are made by each manufacturer with essentially the same phosphors, which results in essentially the same color and the same spectral distribution for all three manufacturers. Consequently, shifts of the test colors under these lamps are pretty much the same in direction and magnitude, regardless of the manufacturer. This is evident in Table 4, particularly for the first three groups of lamps, and is shown in Figure 8 in results for the Standard Cool White.

In the manufacture of the deluxe lamp colors, however, the various makers have different ideas regarding the desired spectral energy distribution and color. Consequently, the rendition is different for each of the test colors. This is evident in Table 4, particularly for the last three lamp groups, and is shown in Figure 9 for the deluxe Cool White, by the wider differences among the colorimetric shifts of the eight test colors.

We have tried to give you a picture of what the color rendering index is and a little insight into how it may be used to bring better and more useful artificial lighting to everyone. We hope we have piqued your curiosity enough to impel at least some of you to begin using this relatively new measuring device. In this way our store of knowledge on its usefulness and its limitations will grow at a faster rate.

Literature Cited

(1) Nickerson, D.: "Light Sources and Color Rendering," Journal of the Optical Society of America, Vol. 50, pp. 57-69 (1960).

(2) News Note: CIE Committee Agrees on Method of Rating Lamps for Color Rendering," Illuminating Engineering, Vol. LIX, No. 1, p. 57 (January 1964).

(3) Committee Report: "Interim Method of Measuring and Specifying Color Rendering of Light Sources," Illuminating Engineering, Vol. LVII, No. 7, p. 471 (July 1962). (Available as reprint, 27 pp., $1.15.)

(4) Wyszecki, G.: "Proposal for a New Color-Difference Formula," Journal of the Optical Society of America, Vol. 53, p. 1318 (November 1963).

(5) Waymouth, J. F., Gungle, W. C., Harris, J. M. and Koury, F.: "A New Metal Halide Arc Lamp." A paper presented at National Technical Conference, 1964.

(6) Crawford, B. H.: "Colour-Rendering Tolerances and the Colour-Rendering Properties of Light Sources," Transactions of Illuminating Engineering Society (Britain), Vol. 28, No. 2, p. 50 (1963).

(7) Barnes, B. T.: "Band Systems for Appraisal of Color Rendition," Journal of the Optical Society of America, Vol. 47, pp. 1124-1129 (December 1957).

(8) Henderson, S. T. and Waight, D. T.: "The Colour-Rendering Properties of Fluorescent Lamps and a Proposed New Method of Specification," Transactions of the Illuminating Engineering Society (Britain), Vol. XVIII, No. 4 (1953).

(9) Kruithof, A. A. and Ouweltjes, J. L.: "Colour-Rendering of Tubular Fluorescent Lamps," Philips Technical Review, Vol. 18, pp. 249-260 (No. 9, 1956/57).

(10) Harrison, W.: "Assessment of Colour Rendering Properties of Fluorescent Lamps," Light and Lighting (April 1951).

(11) Ouweltjes, J. L.: "The Specification of Colour Rendering Properties of Fluorescent Lamps," Die Farbe 4. 202246 December 1960).

(12) Sanders, C. L.: "Color Preferences for Natural Objects," Illuminating Engineering, Vol. LIV, No. 7, p. 452 (July 1959).

Table 1.--Color rendering indices, based on equivalent average vector lengths $\overline{\Delta E}_{u,v}$ or on $\overline{\Delta E}_a$ or $\overline{\Delta E}_i$ as computed from formulas [2] and [3]

R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$	R_a, R_i	$\overline{\Delta E}_{u,v}$	$\overline{\Delta E}_a$, $\overline{\Delta E}_i$
100	0.0000	0.0	75	0.0068	5.4	50	0.0135	10.8	25	0.0203	16.2
99	.0003	0.2	74	.0070	5.6	49	0138	11.0	24	.0205	16.4
98	.0005	0.4	73	.0073	5.8	48	.0140	11.2	23	.0208	16.6
97	.0008	0.6	72	.0076	6.1	47	.0143	11.4	22	.0211	16.9
96	.0011	0.9	71	.0078	6.3	46	.0146	11.7	21	.0213	17.1
95	.0014	1.1	70	.0081	6.5	45	.0149	11.9	20	.0216	17.3
94	.0016	1.3	69	.0084	6.7	44	.0151	12.1	19	.0219	17.5
93	.0019	1.5	68	.0086	6.9	43	.0154	12.3	18	.0221	17.7
92	.0022	1.8	67	.0089	7.1	42	.0157	12.6	17	.0224	17.9
91	.0024	1.9	66	.0092	7.4	41	.0159	12.8	16	.0227	18.2
90	.0027	2.2	65	.0095	7.6	40	.0162	13.0	15	.0230	18.4
89	.0030	2.4	64	.0097	7.8	39	.0165	13.2	14	.0232	18.6
88	.0032	2.6	63	.0100	8.0	38	.0167	13.4	13	.0235	18.8
87	.0035	2.8	62	.0103	8.2	37	.0170	13.6	12	.0238	19.0
86	.0038	3.0	61	.0105	8.4	36	.0173	13.8	11	.0240	19.2
85	.0041	3.3	60	.0108	8.6	35	.0176	14.1	10	.0243	19.4
84	.0043	3.4	59	.0111	8.9	34	.0178	14.3	9	.0246	19.7
83	.0046	3.7	58	.0113	9.0	33	.0181	14.5	8	.0248	19.9
82	.0049	3.9	57	.0116	9.3	32	.0184	14.7	7	.0251	20.1
81	.0051	4.1	56	.0119	9.5	31	.0186	14.9	6	.0254	20.3
80	.0054	4.3	55	.0122	9.7	30	.0189	15.1	5	.0257	20.5
79	.0057	4.6	54	.0124	9.9	29	.0192	15.3	4	.0259	20.7
78	.0059	4.7	53	.0127	10.2	28	.0194	15.5	3	.0262	21.0
77	.0062	5.0	52	.0130	10.4	27	.0197	15.8	2	.0265	21.2
76	.0065	5.2	51	.0132	10.6	26	.0200	16.0	1	.0267	21.4
									0	.0270	21.6

Note: A vector difference approximating 0.00027 (u,v), or 0.22 NBS units, is approximately equal to a 1% difference in the color rendering index, R.

Table 2.--Examples for three fluorescent lamps of differences between ΔE_a and resulting R based on formula [2], and ΔE_i and resulting R_i based on formula [3]

a) Lamp to be tested: Warm White / Reference illuminant: CIE Standard A

CIE No.	Munsell notation	ΔE_a	ΔE_i	Difference $\Delta E_a - \Delta E_i$	R	R_i	Difference $R - R_i$
1	7.5R 6/4	12.9	13.1	- 0.2	40.7	39.7	+ 1.0
2	5Y 6/4	12.6	12.6	0	42.0	42.0	0
3	5GY 6/8	1.6	2.4	- 0.8	92.6	89.0	+ 3.6
4	2.5G 6/6	14.6	14.0	+ 0.6	32.8	35.6	- 2.8
5	10BG 6/4	13.6	13.4	+ 0.2	37.4	38.4	- 1.0
6	5PB 6/8	10.7	10.5	+ 0.2	50.8	51.7	- 0.9
7	2.5P 6/8	9.1	9.3	- 0.2	58.1	57.2	+ 0.9
8	10P 6/8	18.5	20.3	- 1.8	14.9	6.6	+ 8.3
Average		11.7	12.0	- 0.3	46.1	45.0	+ 1.1

b) Lamp to be tested: White[1] / Reference illuminant: Planckian radiator 4300K

1	7.5R 6/4	0.43	0.52	- 0.09	98.0	97.6	+ 0.4
2	5Y 6/4	1.04	0.91	+ 0.13	95.2	95.8	- 0.6
3	5GY 6/8	2.33	2.30	+ 0.03	89.3	89.4	- 0.1
4	2.5G 6/6	1.24	1.37	- 0.13	94.3	93.7	+ 0.6
5	10BG 6/4	0.40	1.62	- 1.22	98.2	92.5	+ 5.7
6	5PB 6/8	0.80	1.34	- 0.54	96.3	93.8	+ 2.5
7	2.5P 6/8	3.56	3.49	+ 0.07	83.6	83.9	- 0.3
8	10P 6/8	1.09	1.11	- 0.02	95.0	94.9	+ 0.1
Average		1.36	1.58	- 0.22	93.7	92.7	+ 1.0

c) Lamp to be tested: Daylight / Reference illuminant: CIE Standard C

1	7.5R 6/4	1.83	1.80	+ 0.03	91.6	91.7	- 1.0
2	5Y 6/4	1.78	1.64	+ 0.14	91.8	92.5	- 0.7
3	5GY 6/8	1.99	1.87	+ 0.12	90.8	91.4	- 0.6
4	2.5G 6/6	1.52	1.38	+ 0.14	93.0	93.7	- 0.7
5	10BG 6/4	1.55	1.54	+ 0.01	92.9	92.9	0
6	5PB 6/8	1.24	1.52	- 0.28	94.3	93.0	+ 1.3
7	2.5P 6/8	0.64	0.80	- 0.16	97.1	96.3	+ 0.8
8	10P 6/8	4.58	4.70	- 0.12	78.9	78.4	+ 0.5
Average		1.89	1.91	- 0.02	91.3	91.2	+ 0.1

[1] In the United States, fluorescent White lamps are about 3500-3600K, fluorescent Cool White lamps are about 4200-4500K.

Table 3.--Colorimetric Data - Lamps Used in Correlation Study

No.	Lamp Description	CIE u	CIE v	Reference standard	Differences Δu	Differences Δv	R	Y	GY	G	BG	PB	P	rP	Av.	R_a 1/	FM 2/
1	Del.Exam. Inc.	.1964	.3058	7500AG	.0011	-.0020	20	20	25	19	22	27	14	17	20	93	100
2	White	.2315	.3410	3600K	.0014	-.0017	124	69	8	132	126	102	69	174	100	63	742
3	Warm White	.2481	.3452	3000K	.0019	-.0022	144	79	34	165	155	126	98	211	126	53	757
4	Daylight	.1946	.3124	7000AG	.0036	-.0055	72	43	32	67	58	68	34	102	60	78	909
5	Cool White	.2186	.3318	4200K	.0028	.0000	107	60	18	110	105	86	66	154	88	67	850
6	Cool White Del.	.2244	.3287	4200K	-.0030	.0031	35	39	49	46	39	59	47	33	43	84	963
7	Warm White Del.	.2506	.3451	3000K	-.0006	.0023	51	47	52	65	66	77	60	89	63	77	870
8	Soft White	.2358	.3250	3400K	.0020	.0170	69	99	129	94	72	128	120	119	104	62	843
9	Natural	.2361	.3225	3900K	-.0105	.0129	31	69	100	63	26	91	80	41	63	76	894
10	Sun Gun	.2391	.3406	3400K	-.0013	.0014	5	7	8	1	4	8	6	2	5	98	1024
11	Sun Gun & Blue Filter	.1952	.3172	6500J	.0024	.0049	30	35	41	33	26	43	36	41	36	87	1001
12	E-HI	.1747	.3231	6500J	.0229	-.0108	319	196	57	251	268	261	134	291	222	18	331
13	Theor. E-HI	.1933	.3086	6500J	.0000	.0000	320	201	95	268	262	292	190	318	243	10	344
14	Metalarc	.1903	.3211	6100K	.0125	.0077	65	47	39	56	66	54	26	99	57	79	894
15	U.V. Examolite	.2000	.3117	6500J	-.0024	.0006	6	11	23	15	6	17	17	13	13	95	

Vector lengths x 10^4.

1/ R_a, CIE Index of Color Rendering.

2/ FM, Crawford's Figure of Merit.

Table 4.--Colorimetric Data - F40T12 Lamps - Three Manufacturers

Lamp description	CIE u	CIE v	Reference standard	Differences Δu	Differences Δv	R	Y	GY	G	BG	PB	P	rP	Av.	Rating R_a
Std. Warm White 1	.2481	.3478	3000K	.0019	-.0004	145	79	15	167	158	134	87	209	124	54
2	.2486	.3474	3000K	.0014	.0000	147	78	18	168	159	125	90	212	125	54
3	.2479	.3452	3000K	.0021	.0022	144	79	34	165	155	126	98	211	126	53
White 1	.2297	.3436	3600K	.0032	-.0043	136	75	10	146	140	107	68	189	109	60
2	.2337	.3415	3600K	-.0008	-.0022	130	70	5	138	130	104	70	179	103	62
3	.2316	.3410	3600K	.0013	-.0017	124	69	8	132	126	102	69	174	100	63
Std. Cool White 1	.2148	.3318	4500K	.0022	-.0035	105	56	6	107	100	74	54	149	81	70
2	.2180	.3330	4400K	.0004	-.0036	116	56	8	108	100	75	55	149	81	70
3	.2187	.3318	4400K	-.0003	-.0024	103	56	5	102	97	77	55	142	80	70
Daylight 1	.1943	.3163	6500AG	.0067	.0062	82	47	21	80	74	52	37	113	63	77
2	.1942	.3148	6500AG	.0068	.0047	80	50	11	83	78	58	40	115	65	76
3	.1947	.3124	7000AG	.0045	.0055	78	45	17	74	68	49	35	106	59	78
Warm White Deluxe 1	.2546	.3444	3000K	-.0046	.0030	94	64	49	109	109	113	70	124	91	66
2	.2504	.3450	3000K	-.0004	.0024	52	51	62	69	69	85	62	84	67	75
3	.2506	.3451	3000K	-.0006	.0023	51	47	52	65	66	77	60	89	63	77
Cool White Deluxe 1	.2227	.3320	4200K	-.0013	-.0002	70	44	29	74	74	73	43	32	55	80
2	.2228	.3323	4200K	-.0014	-.0005	33	34	46	38	40	51	38	50	41	85
3	.2244	.3287	4200K	-.0030	.0031	51	32	43	40	36	53	41	43	42	84
Soft White 1	.2446	.3304	3400K	-.0068	.0116	84	79	91	97	85	119	100	161	102	62
2	.2445	.3323	3400K	-.0069	.0097	57	65	83	73	60	100	86	91	77	72
3	.2359	.3250	3400K	.0019	.0170	69	99	129	94	72	128	120	119	104	62

Vector lengths x 10^4.

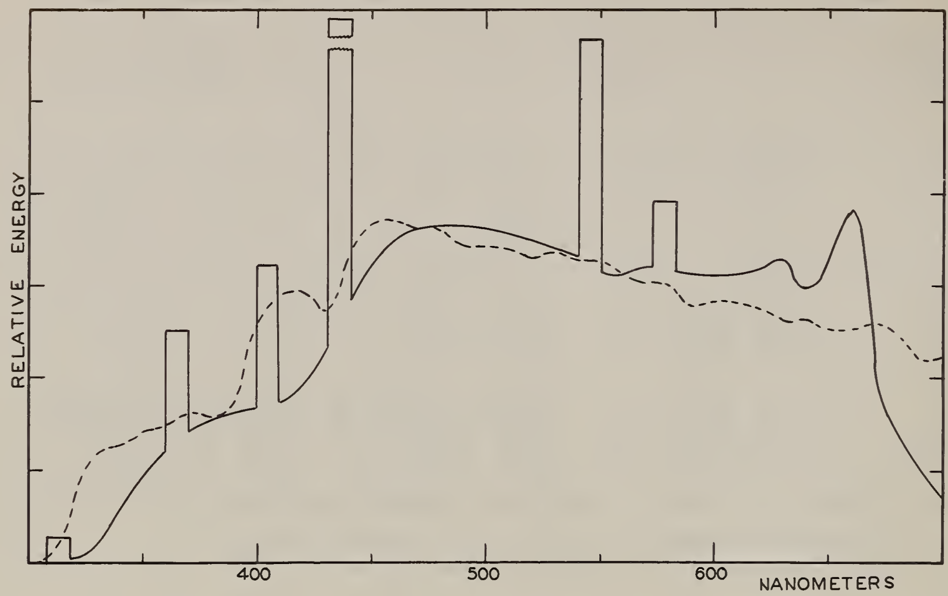


Figure 1. Spectral Energy Distributions at 6500oK. Solid line: F40T12 U.V. Examolite; Dashed line: - Judd Daylight.

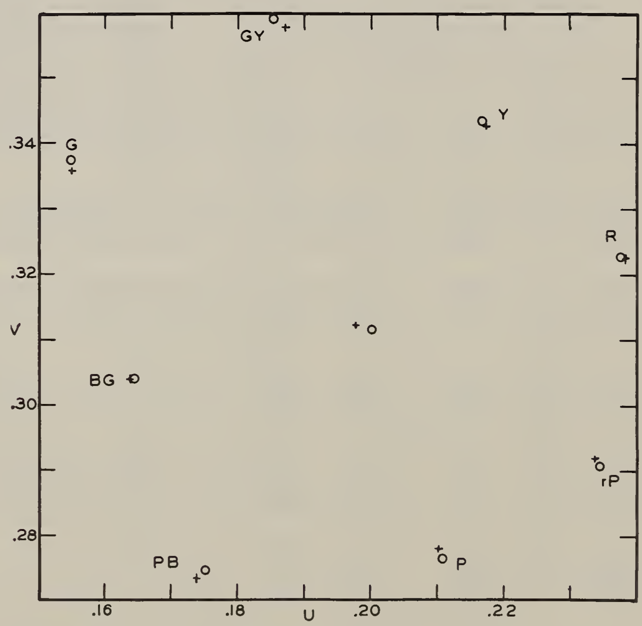


Figure 2. Eight Test Colors on 1960 CIE-UCS Diagram. Crosses, +, under Judd Daylight at 6500oK; Open circles, ○ , under U. V. Examolite (Adjusted).

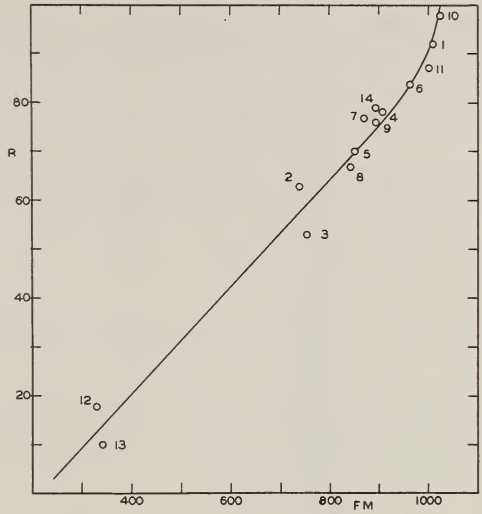


Figure 3. Correlation of Color Rendering Indices. CIE Index, R, vs. Crawford's Figure of Merit, FM. (Points are numbered to correspond with data in Table 3.)

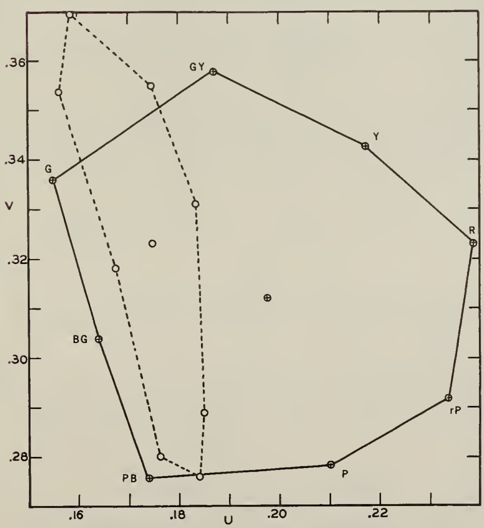


Figure 4. Eight Test Colors on 1960 CIE-UCS Diagram. Crossed circles, ⊕ , and solid line: Under Judd 6500°K Daylight; open circles, ○ , and dashed line, under E-HI lamp.

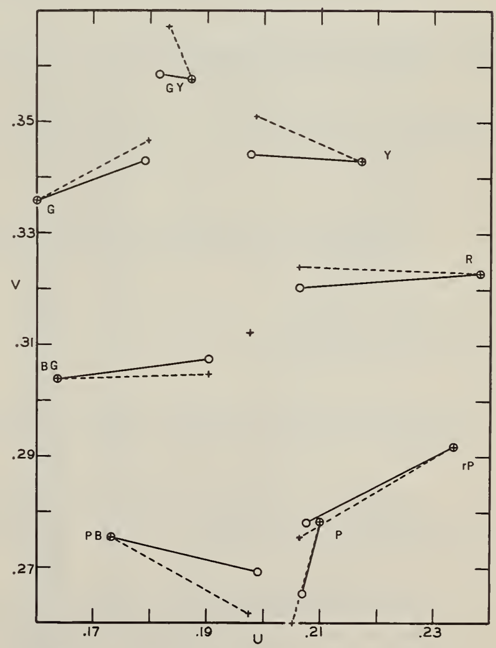


Figure 5. Eight Test Colors on 1960 CIE-UCS Diagram. Crossed circles, ⊕ , under Judd 6500°K Daylight; open circles, ○ , E-HI lamp (Adjusted); crosses, + , under theoretical E-HI lamp.

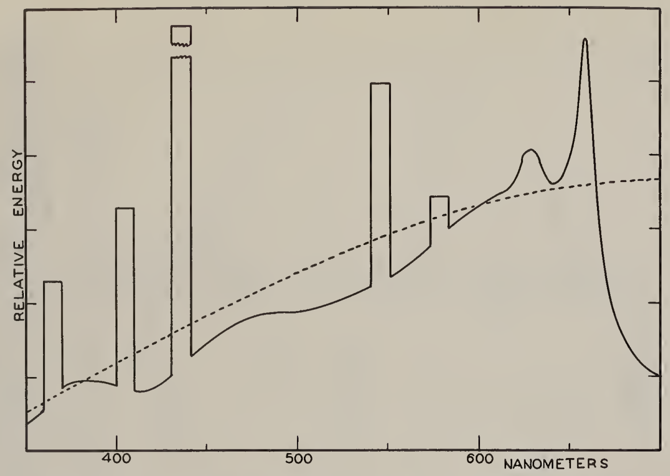


Figure 6. Spectral Energy Distributions. Solid line - F40T12 Natural; Dashed line - Black body @ 3900°K.

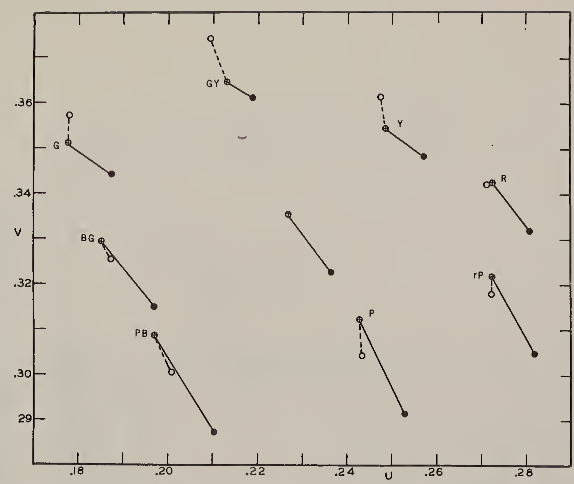


Figure 7. Eight Test Colors on 1960 CIE-UCS Diagram. Crossed circles, ⊕ , under 3900°K; Solid circles, ● , under F40T12 Natural; Open Circles, O , under F40T12 Natural (Adjusted).

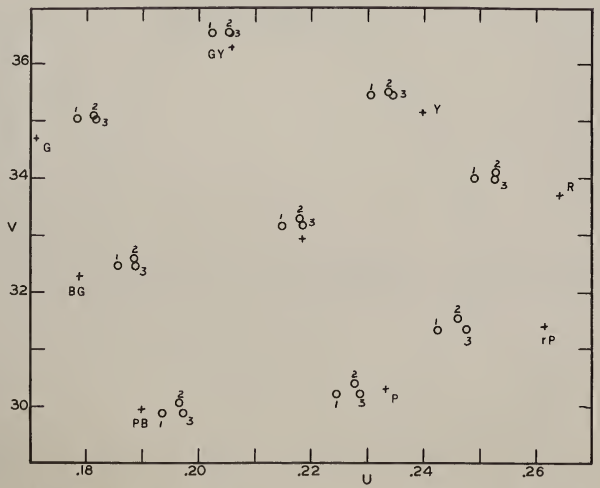


Figure 8. Eight Test Colors on 1960 CIE-UCS Diagram under F40T12 Cool White by Three Manufacturers, open circles; + , under 4400°K.

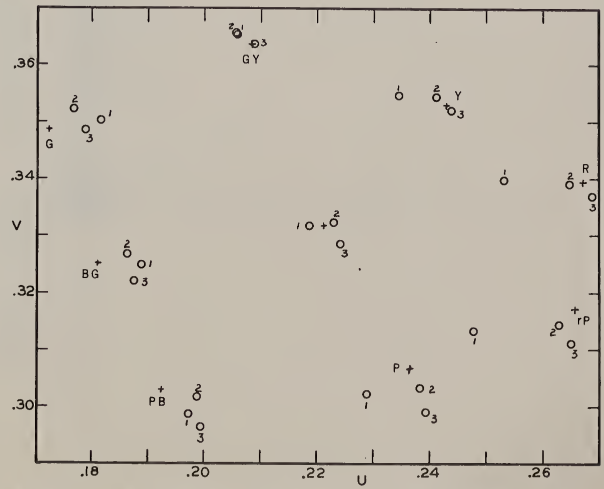


Figure 9. Eight Test Colors on 1960 CIE-UCS Diagram under F40T12 Cool White Deluxe by Three Manufacturers, open circles; + , under 4200°K.

USDA-AMS-Cotton
April 1963

Publications and reports by Dorothy Nickerson

(1) D. Nickerson, How you can know the colors you use. Factory & Industrial Management, pp. 325-326 (1928).

(2) _____, Color measurement of farm products is a factor in grading. U. S. Dept. Agr. Yearbook, 206-8 (1928).

(3) _____, Color discs in soil analysis. Science, 48 (Sept. 28, 1928).

(4) _____, A method for determining the color of agricultural products. U. S. Dept. Agr. Tech. Bull. No. 154, 32 pp., 18 figs. (1929).

(5) _____, Color conversion tables: Table for converting the disk areas of constant brilliance and chroma to color notations in terms of hue, brilliance, and chroma. U. S. Dept. Agr. (Mimeo.) 2 pp., 62 tables (1930).

(6) _____, Color measurements of biological materials. (Paper at AAAS meeting, Bot. Soc. Amer. Sec.) pp. 1-6 (Jan. 1, 1930).

(7) _____, Color: A bird's eye view of the field. Textile Colorist, 52:445-448, 487 (1930).

(8) _____, A colorimeter for use with disk mixture. Optical Soc. Amer. Jour. 21:640-642 (1931).

(9) _____, Color measurements in psychological terms. Optical Soc. Amer. Jour. 21:643-650 (1931).

(10) _____, Measurement of cotton fiber quality in relation to standardization and utilization. Textile World, 80, (24); Amer. Dyestuff Reporter, pp. 4-9 (Jan. 4, 1931).

(11) _____, A note on cotton fibre color. Textile Colorist, 53:805-807 (1931).

(12) _____, Application of color measurement in the grading of agricultural products. A Prelim. Report, U. S. Dept. Agr. (Mimeo.) 36 pp. (1932).

(13) _____, Colorimeter and method employed in color testing of cotton. Proceedings Amer. Soc. Testing Materials, 32:775-777; Textile Bull. 42, (19), (1932).

(14) _____, Cotton fiber quality: Its measurement in relation to standardization and utilization. Amer. Dyestuff Reporter, 21:4-9; Fiber and Fabric, 85:11-14 (Jan. 4, 1932).

(15) _____, Cotton progressively lowered in grade by exposure, tests show. U. S. Dept. Agr. Yearbook, pp. 150-152 (1932).

(16) H. C. Slade, R. E. Betts, and D. Nickerson, A presentation of data regarding variations involved in cotton classification. U. S. Dept. Agr. (Mimeo.) pp. 1-34 (1932).

(17) D. Nickerson and L. D. Milstead, Studies of stability of color in raw cotton. A Prelim. Report. U. S. Dept. Agr. (Mimeo.) 22 pp., 8 figs. (1933).

(18) D. Nickerson, Grade of cotton affected by exposure in the field. U. S. Dept. Agr. (Mimeo.) 12 pp. (1933).

(19) _____, Picking practices affect market grades of cotton. (Lecture Notes for Lantern-Slide Series 183.) U. S. Dept. Agr. (6857) 7 pp. (1933).

(20) _____, Color tables for converting areas of selected disks to terms of hue, brilliance, and chroma. U. S. Dept. Agr. (Mimeo.) pp. 1-8, 117-9 (May 1935).

(21) _____, Disk colorimetry: Including a comparison of methods for computing tristimulus values for certain disks. Optical Soc. Amer. Jour. 25:253-257 (1935).

(22) Anon., Proposed revisions of the universal standards for grades of American Upland cotton. U. S. Dept. Agr. (Mimeo.) 18 pp. (July 1935).

(23) D. B. Judd and D. Nickerson, Review of the spacing of the Munsell colors. (Mimeo.) 6 pp. (Apr. 10, 1936).

(24) D. Nickerson, How can results of fading tests be expressed. Amer. Soc. Testing Materials Standards on Textile Materials, pp. 238-241 (Oct. 1936).

(25) _____, The specification of color tolerances. Textile Res. 6:505-514 (1936).

(26) _____, Use of I.C.I. tristimulus values in disk colorimetry. Prelim. Report. U. S. Dept. Agr. (Mimeo.) 17 pp. (May 1938).

(27) _____, The Inter-Society Color Council. Optical Soc. Amer. Jour. 28:357-359 (1938).

(28) _____, ISCC standard color names. U. S. Dept. Agr. (Mimeo.) AMS (Color Meas. Lab.) pp. 1-7 (1939).

(29) _____, Artificial daylighting for color grading of agricultural products. Optical Soc. Amer. Jour. 29:1-9 (1939).

(30) _____, Artificial daylighting studies. Illum. Engin. Soc. Trans, 34:1233-1253 (1939).

(31) _____, The Colorists of Washington and Baltimore. (Mimeo.) 6 pp. (Jan. 24, 1940).

(32) D. Nickerson and W. C. Granville, Hue sensibility to dominant wave-length change and the relation between saturation and colorimetric purity. Optical Soc. Amer. Jour. 30:159-162 (1940).

(33) D. Nickerson, Standardization of color names: The ISCC-NBS method. U. S. Dept. Agr. (Mimeo.); Amer. Dyestuff Reporter, 29, No. 126 (Aug. 5, 1940).

(34) _____, Computational tables for use in studies of artificial daylighting. U. S. Dept. Agr. (Mimeo.) 31 pp. (1940).

(35) _____, History of the Munsell color system and its scientific application. Optical Soc. Amer. Jour. 30:575-586 (1940).

(36) K. S. Gibson and D. Nickerson, An analysis of the Munsell color system based on measurements made in 1919 and 1926. Optical Soc. Amer. Jour. 30:591-608 (1940).

(37) D. Nickerson, The illuminant in color matching and discrimination: How good a duplicate is one illuminant for another. Illum. Engin. 36:373-399 (1941).

(38) _____, Instructions regarding installation and use of artificial daylighting in cotton classification laboratories. U. S. Dept. Agr. (Leaflet, processed) 4 pp. (June 1941).

(39) D. Nickerson and Sidney M. Newhall, Central notations for ISCC-NBS color names. Optical Soc. Amer. Jour. 31:587-591 (1941).

(40) T. D. Rice, D. Nickerson, A. M. O'Neal, and J. Thorp, Preliminary color standards and color names for soils. U. S. Dept. Agr. Misc. Pub. No. 425, 12 pp. (Sept. 1941).

(41) D. Nickerson, Color stability in raw cotton, II. Storage tests. U. S. Dept. Agr. (Mimeo.) 16 pp. (Oct. 1941).

(42) _____, Supplement to use of I.C.I. tristimulus values in disk colorimetry. U. S. Dept. Agr. (Mimeo.) 4 pp. (Dec. 1941).

(43) _____, Adams' I.C.I. X-Z planes as they relate to studies of uniform chromaticity: Abstract. Optical Soc. Amer. Jour. 31:758 (1941).

(44) _____, Color standards and color names for soils. Soil Sci. Amer. Proc. 6:392-393 (1941).

(45) Milton E. Bond and D. Nickerson, Color order systems, Munsell and Ostwald. Optical Society Amer. Jour. 32:709-719 (1942).

(46) D. Nickerson, Specification and description of color. Amer. Soc. Testing Materials Bull. No. 119:19-20 (1942).

(47) _____, Foreword: Symposium on color blindness. Optical Soc. Amer Jour. 33:293-294 (1943).

(48) K. L. Kelly, K. S. Gibson, and D. Nickerson, Tristimulus specification of the Munsell book of color from spectrophotometric measurements. Optical Soc. Amer. Jour. 33:355-376; Natl. Bur. Standards Jour. Res. (RP 1549) 31:55-76 (1943).

(49) W. C. Granville, D. Nickerson, and C. E. Foss, Trichromatic specifications for intermediate and special colors of the Munsell system. Optical Soc. Amer. Jour. 33:376-385 (1943).

(50) S. M. Newhall, D. Nickerson, and D. B. Judd, Final report of the OSA subcommittee on spacing of the Munsell colors. Optical Soc. Amer. Jour. 33:385-418 (1943).

(51) D. Nickerson and S. M. Newhall, A psychological color solid. Optical Soc. Amer. Jour. 33:419-422 (1943).

(52) D. Nickerson, The ISCC-NBS color names. Amer. Cer. Soc. Bull. 22:306-310 (Sept. 15, 1943).

(53) _____, Colors of soils, foliage, grasses, and camouflage and soil color standards. (For Engin. Board, Nov., unpublished) 20 pp., 5 figs., 26 tables (1943).

(54) _____, Summary of available information on small color difference formulas. Amer. Dyestuff Reporter, 33:252-256 (June 5, 1944).

(55) C. E. Foss, D. Nickerson, and W. C. Granville, Analysis of the Ostwald color system. Optical Soc. Amer. Jour. 34:361-381 (1944).

(56) D. Nickerson and K. F. Stultz, Color tolerance specification. Optical Soc. Amer. Jour. 34:550-570 (1944).

(57) D. Nickerson, K. L. Kelly, and K. F. Stultz, Color of soils. Optical Soc. Amer. Jour. 35:297-300 (1945).

(58) D. Nickerson, Munsell standard colors specified for four illuminants. Illum. Engin. 40:159-171 (1945).

(59) _____, Spacing of the Munsell colors. Illum. Engin. 40:373-386 (1945).

(60) _____, Are new colors limitless. Rayon Textile Monthly, pp. 595-600 (1945).

(61) _____, Selected references relating to the field of color science. Textile Res. Jour. 16:74-83 (1946).

(62) _____, Color measurement and its application to the grading of agricultural products: A handbook on the method of disk colorimetry. U. S. Dept. Agr. Misc. Pub. 580, 62 pp. (1946).

(63) _____, The Munsell color system. Illum. Engin. 41:549-560. illus. (1946).

(64) _____, Color measurement of standards for grades of cotton. Textile Res. Jour. 16:441-449, illus. (1946).

(65) D. Nickerson, Interrelation of color specifications. (Processed) U. S. Dept. Agr. 45 pp., illus.; Paper Trade Jour. 125:153-171, illus. (Nov. 6, 1947).

(66) _____, Effect of cleaning on grade and color of cotton. (Processed) U. S. Dept. Agr. 26 pp., illus. (Apr. 1947).

(67) _____, Color and its description. Amer. Cer. Soc. Bull. 27:47-55 (1948).

(68) _____, The illuminant in textile color matching: An illuminant to satisfy preferred conditions of daylight-match. Illum. Engin. 43:416-464 (1948).

(69) _____, The illuminant in textile color matching: Summary. Optical Soc. Amer. Jour. 38:458-466 (1948).

(70) Norman Macbeth and D. Nickerson, Spectral Characteristics of light sources. Jour. Soc. Motion Picture Engrs. 52:157-183 (1949).

(71) D. Nickerson, A simple method for judging reflectance. Illum. Engin. 44:151-153 (1949).

(72) _____, Bibliography on color. Edited for AIA Color Seminar (Houston 1949) Amer. Institute of Architects 1949 Convention Seminar, pp. 41-52 (1949).

(73) _____, Munsell renotations used to study color space of Hunter and Adams. Optical Soc. Amer. Jour. 40:85-88 (1950).

(74) _____, R. S. Hunter, and M. G. Powell, New automatic colorimeter for cotton. (Processed) U. S. Dept. Agr. (March); Optical Soc. Amer. Jour. 40:446-449 (1950).

(75) _____, Color measurements of cotton: Preliminary report on application of new automatic cotton colorimeter. (Processed) U. S. Dept. Agr. 18 pp. (Apr. 1950).

(76) _____, Foreign-matter content in bales of cotton used for grade standards. Textile Res. Jour. 20:277-278 (1950).

(77) _____ and D. H. Wilson, Munsell reference colors now specified for nine illuminants. Illum. Engin. 45:507-517 (1950).

(78) _____, Tables for use in computing small color differences. Amer. Dyestuff Reporter 39:541-546 (1950).

(79) _____, Certain color changes in cotton under artificial lighting. (Processed) U. S. Dept. Agr. 10 pp.; Optical Soc. Amer. Jour. 40:797 (A) (1950).

(80) _____, New automatic cotton colorimeter for use in cotton quality specification. Textile Res. Jour. 21:33-38 (1951).

(81) R. L. Pendleton and D. Nickerson, Soil colors and special Munsell soil color charts. Soil Sci. 71:35-43 (1951).

(82) D. Nickerson, Effect of exposure and storage on color and other factors of quality in raw cotton. (Processed) U. S. Dept. Agr. 27 pp. (Jan. 1951).

(83) _____, Calibration of scales on Nickerson-Hunter cotton colorimeter. (Processed, for Admin. use) U. S. Dept. Agr. 15 pp. (June 1951).

(84) _____, Cotton classing by artificial light. Illum. Engin. 47:135-142 (1952).

(85) _____, Symposium on color difference specification: Introduction and bibliography. Amer. Soc. for Testing Materials, E-12, pp. 1-8 (Dec. 1952).

(86) _____, Color measurements of cotton: Second report on application of Nickerson-Hunter cotton colorimeter, including a discussion of recent work on standards for grade. (Processed) U. S. Dept. Agr. 38 pp. (1953).

(87) _____, J. J. Tomaszewski, and T. F. Boyd, Colorimetric specifications of Munsell repaints. Optical Soc. Amer. Jour. 43:163-171 (1953).

(88) D. Nickerson, Basis for calibration data supplied with color standards under cotton fiber and spinning testing service Test Item No. 34. (Processed, for Admin. use) U. S. Dept. Agr. 6 pp. (July 1953).

(89) _____, Color of cotton grade standards, 1909-1954. (Processed) U. S. Dept. Agr. 15 pp. (Apr. 1954).

(90) _____, D. B. Judd, and G. Wyszecki, Über eine Transformation des Normvalenzsystems in ein empfindungsgemäss gleichabständiges System auf der Grundlage des Munsell-Systems. Die Farbe, 4:285-288 (955). (This paper presented at international conference on color metrics, Heidelberg, Germany, June 1955.)

(91) D. Nickerson, Achievement of lighting standards for the grading of cotton. U. S. Dept. Agr. AMS-94, 29 pp. (Feb. 1956) (and Proceedings, Marketing Section, Assoc. Sou. Agr. Workers, 53rd Annual Convention).

(92) _____, ISCC-NBS method of designating colors and a dictionary of color names. Natl. Bur. Standards Cir. 553 (book review); Sci. 123: 678-679 (Apr. 20, 1956).

(93) _____, Color measurement data relating to grade standards for cotton and cotton linters. (For Admin. use, prepared for circulation and use at 1956 International Grade Standards Conference) U. S. Dept. Agr. 52 pp., 44 figs., 4 tables (May 1956).

(94) _____, Progress report on color rendition studies. (Paper for Eastern regional meeting of Illum. Engin. Soc.) U. S. Dept. Agr. AMS-126, 24 pp. (June 1956).

(95) _____, A new cotton lustermeter: Abstract. Textile Res. Jour. 26:552 (1956).

(96) D. Nickerson, The Munsell color fan: Modern color science is the background for a new and useful color chart for horticulture for Proceedings 11th annual Amer. Hortic. Congress and annual meeting Amer. Hortic. Council, pp. 3-11 (1956).

(97) _____, A new cotton lustermeter for yarns and fibers. Textile Res. Jour. 27:111-123 (Feb. 1957).

(98) _____, Horticultural Colour Chart names with Munsell key. Optical Soc. Amer. Jour. 47:619-621 (July 1957).

(99) _____, Nickerson Color Fan (40 hues-maxima chromas, 262 color samples arranged by hue on 40 fan leaves, each hue scaled according to value, or lightness). Published by Munsell Color Company, 12 pp. Available also from American Horticultural Council (1957).

(100) _____, Spectrophotometric data for a collection of over 425 Munsell samples for which colorimetric data have been published under several light sources. (Processed) U. S. Dept. Agr. 22 pp. (Oct. 1957).

(101) _____, Color measurements routine in grade standards for cotton and linters. The Cotton Gin & Oil Mill Press, pp. 16,25 (Nov. 30, 1957).

(101a) Physical Society of Japan—Color Science III. A reprint of 20 papers on color, in English and German, distributed to Japanese Physical Society members. Nine of the 20 papers are by Nickerson and associates (1957-8).

(102) D. Nickerson, Measurement and specification of color rendition properties of light sources. Illum. Engin. 53:77-90 (Feb. 1958).

(103) D. Nickerson and J. J. Tomaszewski, Color change in raw cotton related to conditions of storage. Textile Res. Jour. 28:485-497 (June 1958).

(104) D. Nickerson and J. J. Tomaszewski, Sugar, pH, and strength changes in cotton during storage. Textile Res. Jour. 28:528-9 (Letter to Editor) (June 1958).

(105) D. Nickerson and Franklin E. Newton, Grade and color indexes developed for evaluating results of USDA cotton finishing tests. U. S. Dept. Agr. AMS-245, 14 pp. (June 1958).

(106) D. Nickerson, Color measurement and its application to the grading of agricultural products: A handbook on the method of disk colorimetry. U. S. Dept. Agr. Misc. Pub. 580, 62 pp. (1946, reprinted Jan. 1958).

(107) D. Nickerson and J. J. Tomaszewski, Color measurements of grade standards, 1952-1959. No. 1 of 4 reports prepared for 1959 Universal Grade Standards Conference. (Processed) U. S. Dept. Agr. (May 1959).

(108) D. Nickerson and J. J. Tomaszewski, Summary of color measurements from surveys of cottons classed in 8 crop years, 1951 to 1958. No. 2 of 4 reports prepared for 1959 Universal Grade Standards Conference. (Processed) U. S. Dept. Agr. (May 1959).

(109) D. Nickerson, J. J. Tomaszewski, and Franklin E. Newton, Trash and Color. No. 3 of 4 reports prepared for 1959 Universal Grade Standards Conference. (Processed) U. S. Dept. Agr. (May 1959).

(110) D. Nickerson and J. J. Tomaszewski, Color change in storage. No. 4 of 4 reports prepared for 1959 Universal Grade Standards Conference. (Processed) U. S. Dept. Agr. (May 1959).

(111) A.S.T.M.—Recommended Practice for Lighting Cotton Classing Rooms for Color Grading, ASTM D1684. (Tentative, 1959; Adopted, 1961.)

(112) D. Nickerson, Light sources and color rendering. Jour. Opt. Soc. Amer. 50:57-69 (Jan. 1960).

(113) _____, Preliminary report of Subcommittee on Color Rendering, I.E.S. Light Sources Committee. (Feb. 1960 draft contains detailed tables and figures used as basis for summary report to I.E.S.) 68 pp. (Mimeo.) U. S. Dept. Agr., AMS, Cotton (1960).

(114) _____, Cotton Grade Studies, Trash and Color. Preliminary report, 9 pp., Appendix A, 17 pp., Appendix B, 8 pp. (Mimeo.) U. S. Dept. Agr., AMS, Cotton (March 1960).

(115) _____, Cotton Colorimeter, an aid in extending knowledge of cotton quality. A report prepared for the Open House of the American Cotton Manufacturers Institute, Inc., Clemson, S.C. (Processed) U. S. Dept. Agr., AMS. 15 pp. (May 1960).

(116) Anon., Color code for relating color measurements of raw cotton to color in grade standards. U. S. Dept. Agr. AMS-411, 3 pp. (Oct. 1960).

(117) D. Nickerson, Book Review: Seeing Colours by J. Bergmans. Jour. Opt. Soc. Amer. 51, p.465 (April 1961).

(118) _____, COLOR APPEARANCE - Its Specification. 13 pp. Paper presented at joint meeting of ISCC and Colour Group of British Physical Society during Maxwell Centenary, London, May 23-26, 1961.

(119) _____, Recent work on color rendering in the United States. 9 pp., 3 tables, 1 fig. Paper presented at International Colour Meeting, Düsseldorf, Germany, May 23-26, 1961. Die Farbe, 12:69-74 (June 1964).

(120) D. Nickerson, Ch., Progress Report of Subcommittee on Color Rendering, I.E.S. Light Sources Committee. (Oct. 1961 draft.) 79 pp., 21 tables, 5 figs. (Processed) U. S. Dept. Agr., AMS.

(121) D. Nickerson, Recent Trends in Trash Content of Raw Cotton Create a Problem in Grade Standards. U. S. Dept. Agr. AMS-454, 15 pp., 5 tables, 5 figs. (Feb.) Based on report to 1962 National Cotton Council Research Clinic, Pinehurst, N. C., published Textile Bull. 88 (Feb.), pp. 39-45; reprinted by National Cotton Council in "1962 Cotton Research Clinic," 62 pp.

(122) D. Nickerson, Color rendering properties of common light sources and a method for rating them. 15 pp. Paper on "Lighting for Color" Symposium, Inter-Society Color Council. (Mar. 1962.)

(123) D. Nickerson, F. E. Newton, and E. G. Fry, Cotton quality relationships between selected measures of quality and fiber, yarn, and processing properties — multiple statistical relationships, 1946-1960. U. S. Dept. Agr. AIB 257, 137 pp., 59 tables (Apr. 1962).

(124) D. Nickerson, F. E. Newton, and E. G. Fry, Cotton quality relationships between selected measures of quality and fiber, yarn, and processing properties — simple correlations, means, and standard deviations, 1946-1960. U. S. Dept. Agr. Supplement to AIB 257, 248 pp., 117 tables (Apr. 1962).

(125) D. Nickerson, Ch., Report of Subcommittee on Color Rendering of Light Sources Committee, I.E.S.: "Interim Method of Measuring and Specifying Color Rendering of Light Sources." ILLUMINATING ENGINEERING, 57:471-495 (1962). (Available also as IE reprint, 27 pp., $1.15.)

(126) D. Nickerson, Book review: Color of Foods by Gordon Mackinney and Angela C. Little. Jour. Opt. Soc. Amer. (for May 1963); Jour. Assn. Off. Agr. Chem. (for June 1963).

(127) D. Nickerson and S. R. Griffith, Notes on A HISTORY OF UNITED STATES COTTON STANDARDS AND RELATED SUBJECTS— With An Annotated Bibliography. (Processed) U. S. Dept. Agr., AMS, Cotton. (100 copies of May 1964 draft, 61 pp.)

(128) D. Nickerson and J. J. Tomaszewski, Effects of storage on cotton quality: Fiber, spinning, and finishing tests on 38 cottons before and after storage under controlled conditions. (Mimeo.) U. S. Dept. Agr., AMS, Cotton, 43 pp., (Jan. 1964).

(129) D. Nickerson, Color change with change of light source—an unsolved problem in colorimetry. Acta Chromatica (Japan), 1:45-50 (Oct. 1963).

(130) D. Nickerson, CIE Committee agrees on method of rating lamps for color rendering. Illum. Engin., 59:57 (Jan. 1964).

(131) D. Nickerson, Standardization of test samples used to set original scales, and to calibrate Nickerson-Hunter Cotton Colorimeter. 21 pp. (Jan. 1964).

(132) D. Nickerson, Munsell renotation spacing on 1960 CIE-UCS diagram. Jour. Opt. Soc. Amer., 54:573 (A) (April 1964).

(133) A.S.T.M.—Method of test for color of raw cotton using the Nickerson-Hunter Cotton Colorimeter. (D2253-64T) (June)

(134) D. Nickerson, Pattern of color change emerges from 3-year storage study of cotton grades. Letter to the Editor, Textile Research Journal, 34:645-647 (July 1964).

(135) D. Nickerson and C. W. Jerome, Color Rendering of Light Sources: CIE Method of Specification and Its Application. Paper for 1964 I.E.S. Technical Conference, Miami, Florida, Aug. 30-Sept. 3, preprinted, U. S. Dept. Agr., AMS, MQRD (June 1964). (To appear in Illum. Engin., 1964 or 1965.)

Patent

No. 1924747 - Apparatus for Measuring Color

Patent issued to D. Nickerson, August 29, 1933.
(First model disk colorimeter, built by Keuffel and Esser.)